WTI Systems Engineering and Integration of Transportation Technology Program (SEITTP) Feasibility Study, Phase 2

Final Report

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TABLE OF CONTENTS

LIST OF TABLES

EXECUTIVE SUMMARY

Rural and small urban areas face a number of unique transportation challenges including isolated roads in challenging terrain, weather extremes, inadequate public transportation, and the impacts of transportation infrastructure on the environment. Advanced transportation technologies have been beneficial in addressing these challenges and improving rural and small urban transportation. However, these areas are also "particularly susceptible to technical problems related to inadequate systems engineering and integration because of a shortage of personnel experienced with advanced technologies and with the systems engineering process" (1).

The first phase of the WTI Systems Engineering and Integration of Transportation Technology Program (SEITTP) Feasibility Study project considered the practicality of establishing a systems engineering "center of excellence" in an attempt to address these challenges. The result was a feasible concept for a systems engineering program that would provide education, research and application support to client organizations.

Phase 2 of this project sought to compare that original concept with the current Systems Engineering, Development and Integration (SEDI) program area that has since developed. In addition, one of the primary objectives was to outline a future vision for the SEDI group.

Interviews with internal and external stakeholders, and critical analysis by an independent consultant, suggest that the SEDI group is successfully meeting customer needs using a practical systems engineering approach. Generally, the group is functioning and conducting activities as outlined in the original concept document, although the depth and breadth of activities differs from what was originally conceived.

Additional long term strategic planning is needed to provide a framework for future SEDI group activities. Hiring and retaining qualified people, including a dedicated project seeker and a senior staff member, was repeatedly emphasized as critically important to the SEDI group's future. Developing a manufacturing component, continued cultivation of multi-disciplinary relationships, and diversifying the client and partner base were also frequently discussed over the course of this project.

1. INTRODUCTION

The purpose of Phase 1 of this project was to determine the feasibility of a systems engineering and integration center or program at the Western Transportation Institute (WTI) at Montana State University (MSU) in Bozeman. The primary outcome was a concept document which defined the mission, possible application, and needs of such a program. This document indicated that a systems engineering and integration program area within WTI was feasible and had the interest and support of several stakeholders. Many possible project applications were identified.

Following the creation of the concept document, projects emerged, staff members were hired, and a formal program area was established. The strategic plan for the WTI Systems Engineering, Development and Integration group incorporates many of the original principles of the concept document.

However, now is a prudent time to compare the current program with the intent expressed in the concept document. The purpose of this Phase 2 project was to conduct an informal evaluation for the sake of comparison, and to determine the next steps for the program.

In a general sense, the transportation community readily acknowledges that contemporary transportation problems are best addressed using a multidisciplinary approach focused on satisfying end-user needs. The exact manner in which research efforts can be structured to realize this objective is less well understood. The discipline of systems engineering offers a framework for implementing this research approach:

> Systems Engineering is an interdisciplinary approach and means to enable the realization of successful systems. It focuses on defining customer needs and required functionality early in the development cycle, documenting requirements, then proceeding with design synthesis and system validation while considering the complete problem (2).

The Systems Engineering, Development and Integration (SEDI) program area at WTI provides a concrete example of the practical implementation of this framework to solve transportation problems, an example that should be of interest to other transportation research entities around the country.

This document is a final report that describes WTI's experience in developing and implementing a systems engineering approach to transportation research through the Systems Engineering and Integration of Transportation Technology Program (SEITTP).

2. BACKGROUND AND SUMMARY OF PRIOR WORK

The University Transportation Center Strategic Plan prepared by WTI and dated September 6, 2006, states the following in defining how transportation challenges will need to be addressed now and in the future:

> The transportation industry is changing quickly. Where once a single agency could identify problems and affect solutions, now for many problems it takes a collection of organizations working with a team of technical disciplines to generate useable solutions that are optimized across all available modal choices. In addressing almost every need today, and more importantly tomorrow, a paradigm shift will be necessary, from using a single discipline, single technology, single agency, single mode, and single state/nation approach to following a more comprehensive, fully integrated solution strategy. The transportation systems and workforce of the future will need to:
>
> *Integrate* approaches to problem identification, solution, and subsequent performance evaluation,
>
> *Coordinate* between institutions, technologies, modes and systems, and
>
> *Accelerate* moving research results and lessons learned into the hands of practicing professionals (3).

The concept document (Appendix A) drafted in Phase 1 of the WTI SEITTP feasibility study further outlines the needs of the transportation industry, particularly associated with *integration, coordination,* and *acceleration*:

> Development and deployment of advanced transportation technologies is, of necessity, a multidisciplinary process requiring the application of advanced skills in civil engineering, computer science, electrical and computer engineering, industrial engineering, mechanical engineering, human factors engineering, and sciences such as ecology, chemistry, and economics. Currently, the transportation industry has a severe shortage of personnel who have the knowledge and experience to bring these disciplines together into effective teams and solutions, particularly in rural and small urban settings. There is also a lack of knowledge about best management practices for integrating the products of these disciplines (1).

The concept document also specifies these issues in relation to transportation in rural and small urban areas:

> In rural and small urban areas, highway transportation presents a broad spectrum of challenges: isolated roads, limited communications coverage, challenging terrain, extreme weather, inadequate public transportation, and conflicts with the

> environment. Advanced technology has proven beneficial in dealing with these challenges. However, rural and small urban areas are also particularly susceptible to technical problems related to inadequate systems engineering and integration due to a shortage of personnel having experience with advanced technologies and systems engineering processes (1).

To address these challenges, WTI proposed to leverage its existing status and expertise to investigate the establishment of a center for systems integration and engineering as applied to the integration, deployment, and evaluation of complex transportation technologies. The center would bring together a multi-disciplinary team of engineers, scientists, and students from a broad range of university departments to study education, research, and application issues of systems engineering and integration in relation to advanced transportation technology. The concept for the center or new research thrust area within WTI was endorsed by the dean and department heads within the College of Engineering including those from the Civil Engineering, Computer Science, Electrical & Computer Engineering, and Mechanical & Industrial Engineering departments.

Initial outreach to the MSU College of Engineering faculty garnered widespread support for the tenets of systems engineering and integration, but little consensus on a definition for the process. Around the same time, an American Association for the Advancement of Science (AAAS) review of material science programs at MSU stated, "It would appear that the research center programs could benefit by incorporating a systems engineering component." And furthermore, "To have maximum long-term impact, however, particularly in the creation of new local industry and good jobs for graduates, we suggest that it would be helpful to build a systems approach into the research program at the very start" (4).

Incorporating comments, suggestions, and feedback from a multi-disciplinary group of faculty, WTI staff, and a subcontractor, a concept for the WTI SEITTP program was developed. The proposed program was to be dedicated to defining, developing, promoting and applying an integrated and interdisciplinary approach in all aspects of complex and innovative transportation technologies including specification, design, training, integration, deployment, operation, maintenance, and evaluation. The concept document clarified several issues that had been raised by this group. One modification of particular note was changing the name from "Center" to "Program." There was uncertainty expressed regarding the relationship of this proposed entity to WTI. Calling it a program within WTI clarified that issue. Other comments were made regarding whether the focus would be rural or general (rural and urban), or if there would be a national or regional focus. Originally, the concept document addressed these by recognizing a potential focus on both rural and urban transportation with a national target market. Note though that the statement of need was still phrased in the context of rural transportation, which is WTI's area of expertise (1). The SEITTP concept document is in Appendix A.

The mission statement for the SEITTP reads as follows: "The mission of the Systems Engineering and Integration of Transportation Technology Program (SEITTP) is to develop, promote and apply interdisciplinary skills and services necessary to implement best management practices and solutions for the integration of advanced transportation technologies within rural and small urban settings" (1). WTI, through the SEITTP and in conjunction with the Montana State University College of Engineering, would provide education, research and application support for systems engineering and integration to client organizations (1).

WTI was re-designated a University Transportation Center (UTC) in 2005. To meet the goals and objectives for a UTC and to address the requirement of the 2005 transportation bill (Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU)), WTI identified five primary and three secondary research program areas that reflect WTI's technical interests and strengths (3):

- Primary Research Program Areas
  - Safety and Operations
  - Winter Maintenance and Effects
  - Road Ecology
  - Infrastructure Maintenance and Materials
  - *Systems Engineering, Development and Integration*
- Secondary Research Program Areas
  - Logistics and Freight Management
  - Mobility and Public Transportation
  - Transportation Planning and Economics

As its own distinct program area within WTI, the Systems Engineering, Development and Integration (SEDI) group began the strategic planning process with a strengths, weaknesses, opportunities, and threats (SWOT) analysis and proposed the following research core areas/themes (See Appendix B for more details.):

1. **Develop usable information technology and communication systems to meet end user needs.** (Develop/Integrate)
2. **Demonstrate systems engineering processes that leverage best practices to maximize limited resources.** (Demonstrate)
3. **Analyze and evaluate systems and alternatives to recognize capabilities and limitations and to maximize utility.** (Analyze/Evaluate)
4. **Raise awareness of systems engineering via work force development and education at all levels.** (Train/Educate)

In order to compare the current SEDI group with the concepts outlined in the Concept Document (Appendix A), and then use the information gathered to outline a future vision and next steps for the group, the following objectives were established for this project:

1. Review, analyze, and summarize the work done through Phase 1 of the Systems Engineering and Integration of Transportation Technology (SEITTP) feasibility study.
2. Evaluate the initiation, evolution, and status of the current Systems Engineering, Development and Integration program area within WTI. This will include an overview and discussion of current projects and facilities.
3. Gather and compile perspectives on Phase 1 of this project and the subsequent implementation of the WTI Systems Engineering, Development and Integration program area. Views from the inside (WTI personnel, MSU COE faculty), outside (independent, un-biased expert), and from stakeholders (Montana Department of Transportation, California Department of Transportation) will be expressed.
4. Compare and contrast the original intent and concept of the SEITTP with the current Systems Engineering, Development and Integration program within WTI.

5. Outline a future vision for the SEDI program area at WTI.
6. Prepare a final report that documents WTI's experience in developing and implementing a systems engineering approach to transportation research through the SEITTP.

3. METHODOLOGY

To meet the objectives of this project, the research included a document review, oral interviews and analysis, and a goal-setting process.

Task 2: Summary of prior work (Section 2), and *Task 3: Development and status of current program* (Section 4), were primarily accomplished by reviewing the concept document and supporting materials as well as compiling a list of projects, both ongoing and completed, in which the Systems Engineering, Development and Integration (SEDI) group was involved.

Task 4: View from the inside (Section 5.1), and *Task 5: Independent view from the outside* (Section 5.2), were conducted by an independent consultant. This involved personal interviews of seven WTI and COE representatives, including the SEDI group's current program manager. For more details, refer to sections 5.1, 5.2, and 7.1, and Appendix C.

To evaluate stakeholder perspectives (*Task 6)*, the project team conducted oral interviews with two of the primary partners and sponsors of SEDI group projects. A list of questions was developed to guide the interviews but still allow flexibility in collecting relevant information when the opportunity was presented. Interviews were recorded and used in conjunction with real-time notes to complete this task. See Section 6.

Next steps for the program (*Task 7*) were outlined based on the results and responses gathered during previous tasks and an evaluation of the current status and environment surrounding the SEDI group. The group was also involved with WTI's recent marketing and positioning efforts. Over the course of several months and with guidance from a marketing firm, WTI developed a marketing plan that included strategic recommendations for the organization as a whole. Each program area, including the SEDI group, set two to five goals and success criteria for each of six marketing areas. Those areas were reputation-building, networking, publishing, cross-fertilization, presentation, and media outreach. These goals and recommendations were used to help guide and determine the next steps for the SEDI group (Section 7).

4. DEVELOPMENT AND STATUS OF CURRENT PROGRAM

The SEDI group became one of five formal program areas when WTI was re-designated a UTC in 2005. Prior to that, WTI was organized by focus areas with no formal management structures or a system to assign projects to a particular focus area.

The SEDI group emerged as one of the primary program areas due in large part to an increasing number of opportunities for applying systems engineering processes to meet the growing needs of rural transportation. The SEDI group has grown in many ways since its inception. Staffing levels and capabilities, facilities, number of projects, and scope of work have all increased and expanded in response to the increased need.

Starting with four researchers, the group has added a number of people to increase group capabilities and more effectively address increasing needs. The involvement of students and affiliated COE faculty has also complemented the capabilities of the group and has been a crucial component of several projects. While the number of staff members and students has varied over the years, the SEDI group currently consists of nine staff members and two undergraduate students. A position announcement for another senior level staff member was posted recently and the intent is to fill that position early next year.

Facilities have grown along with SEDI group staffing, capabilities, and projects. No laboratory space was available in the first two WTI locations. When WTI moved to its third location in 2006, there was a general impetus for creating laboratory space along with an increased need for the SEDI group to have a dedicated research area. The SEDI group brought the Systems Lab online as well as an IT lab/workspace. Like WTI overall, the SEDI group eventually outgrew these spaces as project work evolved. In the spring of 2009, WTI moved into its current facility. To meet present and future needs, the SEDI group designed and is responsible for over 3,000 square feet comprising the new Systems Engineering Development and Integration Laboratory, control/server room, and the IT Laboratory. Other new or improved features include private networking, space to accommodate electrical engineering efforts, metal-working equipment, and a 15-foot mast on the roof of the new building for testing radio frequency (RF) systems. The facilities were designed with an eye towards the future and dedicated room to grow. Past experience and limitations also contributed to the design of the new facilities. It should be noted that SEDI group members are also functionally assigned to and technically responsible for the Transportation Research Application and Instrumental Laboratory (TRAIL), Driving Simulator Laboratories, and the ITS trailers.

The number and scope of the projects conducted by the SEDI group has steadily increased as the group has expanded and evolved. The current annual budget for the SEDI group is approximately $2 million. There has also been a concerted effort to work on projects with other WTI program areas in addition to interdisciplinary work with the College of Engineering. It is important to note that the SEDI group has been successful as a program area in its own right as well as in a supportive role for various forms of information technology, both organizationally and with other program areas' projects. SEDI group members are currently leading or co-leading at least 10 different projects and have an active role (technical lead) in at least 10 others. To gauge the scope of the SEDI group's work, Table 1 shows a list of current and completed projects, including project sponsors and partners.

Table 1: SEDI Group projects, sponsors, and partners.

Title	Sponsors and Partners
Redding Responder – Phase 2	Caltrans DRI; Caltrans District 2
Weathershare – Phase 2	Caltrans DRI; Caltrans District 2
Automated Safety Warning System Controller	Caltrans DRI; Caltrans District 2
Integration of Aviation Automated Weather Observation System with RWIS	Mineta Transportation Institute (San Jose State University); Caltrans; USDOT/Research and Innovative Technologies Administration
Mobile Communication Briefcase – UTC	USDOT/Research and Innovative Technologies Administration
PDA Data Collection Package (in partnership with the WTI Road Ecology Program Area)	Federal Highway Administration
Professional Capacity Building for Communication Systems	Caltrans Division of Research & Innovation (DRI)
Ant Colony Optimization for Transportation Optimization Problems – UTC	USDOT/Research and Innovative Technologies Administration
WTI System Engineering and Integration of Transportation Technology Program (SEITTP) Feasibility Study, Phase 2	USDOT/Research and Innovative Technologies Administration
Facilitating Special Event Congestion Management in Small Communities – UTC (in partnership with the WTI Safety and Operations Program Area)	USDOT/Research and Innovative Technologies Administration; MSU Police Department; MDT; City of Bozeman; Bozeman Police Department
Systems Engineering Development & Integration Lab, Phase 2	USDOT/Research and Innovative Technologies Administration
COATS Phase 4; Western States Rural Transportation Technology Implementer's Forum (in partnership with the WTI Safety and Operations Program Area)	Caltrans
One-Stop Shop Phase 1 (in partnership with the WTI Safety and Operations Program Area)	Caltrans

Table 1, continued: SEDI Group projects, sponsors, and partners.

Title	Sponsors and Partners
PATIS—Portable Advanced Traveler Information System (in partnership with the WTI Safety and Operations Program Area)	Caltrans; California Center for Innovative Transportation (CCIT)
COATS Phase 3; Integrated Corridor Management (in partnership with the WTI Safety and Operations Program Area)	Caltrans
MANETs for Rural Public Safety (in partnership with the MSU COE Electrical and Computer Engineering, and Computer Science Departments)	U.S. Department of Homeland Security; Hot Springs County, Wyoming
American Wildlands Road Watch	American Wildlands
An Integrated PDA/GPS System to Collect Standardized Road Kill Data (in partnership with the WTI Road Ecology Program Area)	FHWA; Washington DOT; Virginia DOT; Parks Canada
Improve Communications Between TMC & TMS Elements in A Rural Environment Through A System That is Deployable Statewide	Caltrans
Portable TMC–TMS Communications Demonstration – UTC	Caltrans
Trailer Configuration & Deployment–UTC	USDOT/Research and Innovative Technologies Administration
Transportation Research Applications and Instrumentation Laboratory (TRAIL)	USDOT/Research and Innovative Technologies Administration
Bozeman TRAIL Project (in partnership with the WTI Safety and Operations Program Area)	USDOT/Research and Innovative Technologies Administration
511 in YNP (in partnership with the WTI Safety and Operations Program Area)	Yellowstone National Park; Meridian Environmental Inc.; MDT
Validate Percent Wet Time Statewide (in partnership with the WTI Safety and Operations Program Area)	Caltrans

Table 1, continued: SEDI Group projects, sponsors, and partners.

Title	Sponsors and Partners
Responder Field Test – UTC	Caltrans DRI; Caltrans District 2
Development of a Prototype Integrated PDA/GPS System to Collect Roadkill Data (in partnership with the WTI Road Ecology Program Area)	USDOT/Research and Innovative Technologies Administration
Developing a Regional Ecosystem Framework for Terrestrial & Aquatic Resources along the I-70 Corridor, CO (in partnership with the WTI Road Ecology Program)	CDOT; Center for Native Ecosystems; CO Watershed Assembly; CO State University; Rocky Mountain Insurance Information Association; CO State Patrol; CO Div. of Wildlife
Traveler Info Database Requirements Analysis (in partnership with the WTI Safety and Operations Program Area)	Montana Department of Transportation (MDT)
Enhancement of Statewide Operations Concept of Operations Report (TMC) (in partnership with the WTI Safety and Operations Program Area)	Montana Department of Transportation (MDT)
Redding District Incident Management Responder Study	Caltrans District 2; Caltrans DRI; Redding Incident Management Program Participants (RIME)
National Center for Integration and Systems Engineering of Transportation Technology Feasibility Study	MSU College of Engineering; USDOT/Research and Innovative Technologies Administration
Narrows Oversize Vehicle Identification System (Showcase Evaluation #13) (in partnership with the WTI Safety and Operations Program Area)	Caltrans
Safe Passage: Development and Demonstration of a Rural Weather Prediction Model and Motorist Communication System for Safe and Efficient Traffic Management/Infrastructure Maintenance (in partnership with the WTI Safety and Operations Program Area)	MDT; USDOT/Research and Innovative Technologies Administration

Over the course of the SEDI group's development, the direction of the group has arguably been affected most by staffing levels and capabilities. It has been a challenge to hire and retain qualified people to fill the necessary roles required for project work, which directly impacts the SEDI group's strategic ability to increase and diversify their contributions to rural transportation research. While all of the SEDI group staff members are certainly qualified in technical skills, the challenge has been to balance hands-on experience with more traditional, academic research capabilities. The SEDI group has chosen to focus on staff member strengths and has placed more emphasis on hands-on field experience in response to the nature of the needs and opportunities presented to the group by sponsors and partners. The result is real research and development that is perhaps less theoretical in nature, but definitely appropriate for this type of organization.

5. VIEW FROM THE INSIDE/INDEPENDENT VIEW FROM THE OUTSIDE

The purpose of *Task 4 (View from the inside)* was to evaluate the SEDI group's development, activities, and potential from the perspective of WTI personnel and COE faculty involved in the SEITTP project and/or SEDI group research. *Task 5 (Independent view from the outside)* sought to independently review and evaluate the progression of this project from the original vision and mission for a Center of Excellence for Systems Engineering and Integration to its current implementation as a program area within WTI. Recommendations were made as to how WTI and the SEDI group should proceed with future related efforts. Both tasks were completed by an independent consultant. The results of *Task 4* are summarized below in section 5.1. Section 5.2.1 summarizes the consultant's findings regarding the SEDI group's efforts to fulfill its stated mission and objectives.

Sections 5.1 and 5.2.1 are adapted from the consultant's report and the views expressed therein are his. Unless otherwise identified, quotations found in these sections are from the people he interviewed for his report, including WTI staff and COE faculty. They are not named to preserve their anonymity.

Finally, to best meet the objectives of this project, the project team chose to include in its entirety the independent consultant's comparison of the original SEITTP concept and the SEDI group's actual implementation. This is found in Section 5.2.2 and also in Appendix C.

Appendix C presents the consultant's complete findings and analysis.

5.1. Task 4: View from the Inside (Summary)

The SEDI group is perceived overall as professional and responsive to sponsor needs. Projects are conducted using methodologies that follow best practices of systems engineering in a practical, applied way. Group members possess complementary and applicable skill sets and work well together. The SEDI group is successfully leveraging these strengths to be particularly efficient and effective in its work. As expressed by this project's independent consultant, "It is clear that the Group is working very well within the well-defined area of applying systems engineering processes to clearly define sponsors' requirements and to integrate applicable technologies to solve IT- and communications-centric problems in a transportation-focused environment."

The program manager was described as a "linchpin" for the group and crucial to the group's capabilities. However, the staff as a whole is relatively immature in a professional sense. Coupled together, the critical value of the program manager inevitably becomes a weakness as well. Funding the staff with 100 percent "soft money," limited financial resources, and scope creep are other perceived weaknesses identified through *Task 4: View from the inside*.

Interviewees were challenged to identify and explain how to take advantage of the opportunities available to the SEDI group and a number of questions arose over the course of the interviews. Is the SEDI group (and its projects) a discipline area in its own right or is its role a supportive one? What should the group's focus be: information technologies and communications related to transportation or systems engineering as its own discipline area with applications outside the transportation realm?

Another topic discussed was the other opportunities that are certainly available but not being pursued. One that was mentioned repeatedly is more collaboration with the MSU COE. Furthermore, the consultant observed that while the SEDI group's activities are viewed favorably by sponsors, continued dependence on the same sponsors may be concealing other opportunities. The consultant warned that such dependence may ultimately cause a "system failure should champions within those organizations move on or just change their minds."

Openings in the private sector are not being capitalized upon, according to one interviewee. The consultant reported that one possible means of taking advantage of available opportunities using the "best of private and public sector interests," is a national communications test bed that would facilitate exploration of new technologies with a distinctly rural focus.

The threats to the SEDI group as perceived by the interviewees all dealt largely with either competition or remote location. There are a large number of potentially competing organizations, some based at universities and some in the private sector. While remote location is a strength for understanding and addressing rural transportation issues, it can also be detrimental if only in the stigma it can produce. For example, transportation department managers in larger states with more urban areas tend to look towards larger, better-known entities rather than a "small organization in some cow town in Montana," as one party interviewed by the consultant put it.

5.2. Task 5: Independent View from the Outside

5.2.1. Mission Area Fulfillment (Summary)

The overall goal of the SEDI group is to research and apply best practices to analyze, engineer, develop and integrate hardware, software, and communication systems as applied to transportation. To accomplish this, the following objectives were established. See also Appendix B.

1. **Develop usable information technology and communication systems to meet end user needs.** (Develop/Integrate)
2. **Demonstrate systems engineering processes that leverage best practices to maximize limited resources.** (Demonstrate)
3. **Analyze and evaluate systems and alternatives to recognize capabilities and limitations and to maximize utility.** (Analyze/Evaluate)
4. **Raise awareness of systems engineering via work force development and education at all levels.** (Train/Educate)

In regard to developing information technology and communications systems, the consultant concluded that there is no doubt that the SEDI group is meeting this objective very well. Sponsors continue to bring new project ideas to the group with confidence that their needs will be met with a practical and advantageous solution.

Interviewees said the SEDI group was certainly meeting sponsor needs/requirements and that to do so meant it was implementing "best practices." While noting that the concept of "best practices" can carry multiple meanings, the consultant offered the following definition: "the integrated knowledge base a practitioner develops as a result of experiences, often with reference

to published standards and lessons-learned white papers and studies." In practice for the SEDI group, this translates to using commercial, off-the-shelf, proven technologies and existing infrastructure whenever possible to develop a practical solution that meets sponsor needs. This requires group members to remain up to date and knowledgeable about new and relevant technologies. However, the SEDI group lacks the human and financial resources required to develop new "best practices."

Additionally, the SEDI group is competent at analyzing and evaluating systems for existing sponsors and IT-related projects. A logical next step for the SEDI group may be to extend its work outside the IT sphere.

Overall, the SEDI group is excelling at engaging students in research and systems engineering processes, a mutual benefit to all parties. Staff members also feel they have benefitted from the project work conducted by the SEDI group. On the other hand, the impact of the SEDI group's activities on practitioners is more difficult to assess. Coordinating and presenting at the Western States Rural Transportation Technology Implementers Forum has been an opportunity to participate in technology transfer involving systems engineering processes and meet the objective of educating and developing the work force.

In conclusion, the consultant noted that the SEDI group's core constituencies (i.e., transportation-related groups) continued to provide follow-up work. This is evidence that these constituents are satisfied with the SEDI group's response to their requirements.

5.2.2. Planned vs. Actuals: The Original SEITTP Concept and the Group's Implementation

Note: This section (5.2.2) is taken from the independent consultant's report WTI Center of Excellence Feasibility Study Phase 2 (Tasks 4, 5). For the complete report, see Appendix C. Note that the SEDI group is referred to as SEDIG.

To determine how well the Group as implemented embodies the precepts brought forth in the original SEITTP "Center of Excellence" document, referred to earlier, the original SEITTP draft concept document was parsed into core areas that formed the underpinnings of the operational approach. These core areas were then mapped to cognate Group activities, with differences and/or similarities between the two noted.

[N.B.: Owing to similarity in analysis across the several sections addressed, there is some duplication of text in the Commentary sections. This is intentional.]

5.2.2.1. SEITTP Focus Area Concept: Education

The original document put forth the tenet that the Program should provide work force development and continuing education opportunities in systems engineering and integration for transportation professionals. It will promote systems engineering and integration training as part of the undergraduate and graduate engineering curriculum, and will provide students with the opportunity to apply what they've learned in the classroom to "real-world" problems.

5.2.2.1.1. SEDIG Implementation

Opportunities for both graduate and undergraduate students are provided. These opportunities provide real-world, hands-on learning environments.

While there have been opportunities to provide input to graduate (master's) theses, the program manager having been involved in three of these, there is no clear integration with curriculum development *per se* within the COE.

5.2.2.1.2. Comparative Analysis

The Group activities provide student opportunities, but there have been limited continuing education opportunities for professionals already engaged in relevant work, despite the program manager's efforts to share the benefits of the Group's experience, particularly as regards process. Such limited incursion appears largely due to entrenched conservatism in the transportation community generally.

The SEITTP concept addressed SE/I opportunities in a very general sense, i.e., for advanced transportation technologies, yet the Group focus is virtually entirely on information technologies.

5.2.2.1.3. Commentary

At least three interviewees (but not Group members) acknowledged that when they think of SE/I, they think in terms of systems generally, and that IT and communications are subsets of larger systems, against which SE/I processes could be brought to bear.

Most WTI staff, however, stated that the IT-centric view is that of the U.S. Department of Transportation, and so that is their emphasis.

Given the degree to which the Group takes its lead from the program manager, whose background is in IT and related areas, this centrism is not unexpected.

If, as noted below and elsewhere, the Group were to broaden its focus, there would be many more opportunities to work with more faculty members in more departments in the CoE, both as regards projects and curricular integration.

5.2.2.2. SEITTP Focus Area Concept: Research

Providing multidisciplinary transportation-related research and development opportunities for engineering and science faculty, staff and students, and will use and promote WTI, COE and other MSU labs and facilities for systems integration efforts. It will use technology transfer and the publishing of research results to promote the application of transportation-related research in systems engineering and integration.

5.2.2.2.1. SEDIG Implementation

Historical and ongoing Group projects address advanced information technologies as applied to transportation problems. The outcomes clearly benefit the sponsors and are responsive to their needs and requirements.

There is some partnership and collaboration with MSU COE faculty. Presentations—either as lectures at MSU venues or at professional society/group meetings of historical and ongoing projects appear to be limited, owing to other demands on the project manager's time (as he has primary responsibility for such communication), or because of lack of overlap of interests (in the case of COE departments).

5.2.2.2.2. Comparative Analysis

The SEITTP concept was predicated on there being a large number of partnerships and collaborations between WTI/SEDI Group members and COE faculty. The reality is that the number of these is relatively few as regards projects, and even fewer as regards the number of faculty and departments involved, despite the apparent early buy-in by faculty during the formative SEITTP discussions.

With the emphasis on technology development, and the observed lack of writing skills on the part of Group staff, there appears to be only a small amount of technology transfer per se (other than deliverables to the sponsors). The program manager does make attempts in this direction, and with some success, with some development and promulgation of process advances.

5.2.2.2.3. Commentary

At least three interviewees (but not Group members) acknowledged that when they think of SE/I, they think in terms of systems generally, and that IT and communications are subsets of larger systems, against which SE/I processes could be brought to bear.

Most WTI staff, however, stated that the IT-centric view is that of the U.S. Department of Transportation, and so that is their emphasis.

Given the degree to which the Group takes its lead from the program manager, whose background is in IT and related areas, this centrism is not unexpected.

If, as noted below and elsewhere, the Group were to broaden its focus, there would be many more opportunities to work with more faculty members in more departments in the CoE.

5.2.2.3. SEITTP Focus Area Concept: APPLICATION

Supporting the development of emerging transportation technologies, and assisting to evaluate and implement state-of-the-art technology, evaluating existing conceptual design products under actual use conditions, and developing and providing best management practices for integration of these technologies.

5.2.2.3.1. SEDIG Implementation

The Group is clearly applying best management practices to choices of technologies to address sponsors' requirements and to develop applicable and useful solutions thereto. COTS technologies and existing infrastructure are routinely employed where possible, and new technologies are implemented only when existing solutions are not responsive.

5.2.2.3.2. Comparative Analysis

The Group addresses this focus area very well, with the caveat that their activities are almost entirely IT-centric.

5.2.2.3.3. Commentary

At least three interviewees (but not Group members) acknowledged that when they think of SE/I, they think in terms of systems generally, and that IT and communications are subsets of larger systems, against which SE/I processes could be brought to bear.

5.2.2.4. SEITTP Focus Area Concept: WTI POSITIONING

Positioning WTI to be better able to effectively address the transportation challenges that rural and small urban areas present.

5.2.2.4.1. SEDIG Implementation

A key manifestation of the Group's utility is its expertise in the increasingly acknowledged niche area of rural transportation issues. Rural areas present transportation challenges that are unique; responses to large urban challenges are not easily transferred to rural areas, especially in the communications realm.

5.2.2.4.2. Comparative Analysis

The Group addresses this focus area very well, with the caveat that their activities are almost entirely IT-centric.

5.2.2.4.3. Commentary

At least three interviewees (but not Group members) acknowledged that when they think of SE/I, they think in terms of systems generally, and that IT and communications are subsets of larger systems, against which SE/I processes could be brought to bear.

5.2.2.5. SEITTP Focus Area Concept: ATTRACTING STAFF

Attracting a high-quality engineering and scientific staff to Montana State University.

5.2.2.5.1. SEDIG Implementation

One interviewee commented that it was the presence of and access to WTI (generally) that influenced his decision to accept a position in the COE at MSU. No other data were sought.

5.2.2.5.2. Comparative Analysis

The staff at WTI (a MSU exponent) is of high quality and professionalism, but it is was not within the purview of this task to determine the extent to which WTI's reputation caused its staff to choose a position at WTI specifically.

5.2.2.5.3. Commentary

No comments.

5.2.2.6. SEITTP Focus Area Concept: REGIONAL INFRASTRUCTURE

Creating a stronger research infrastructure available to many organizations in Montana and neighboring states.

5.2.2.6.1. SEDIG Implementation

The Group's professionalism is clear, and the sum total of their body of work clearly shows the strength of and potential for WTI generally (and the Group, specifically) to augment the region's infrastructure in relevant disciplines.

5.2.2.6.2. Comparative Analysis

At least two interviewees commented that there are likely significant opportunities for the Group both within the state and the surrounding region. Explicit statements were made that inroads into cognizant organizations was not as deep as it could be.

5.2.2.6.3. Commentary

No comments.

5.2.2.7. SEITTP Usage Scenarios

Given the breadth of usage scenarios offered in the draft concept document as having potential for the SEITTP, there is little utility in a detailed analysis and comparison of those scenarios vs. projects addressed by the Group, given the small size of the extant Group. Those scenarios speak to a wider range of potential SE/I-related activities than the IT- and communications-centric choices made by the group. The current consultant takes this disconnect to support his contention that the SEDI Group has at least the potential for a far wider range of possible projects than currently being addressed, and that the SEITTP concept was formulated with this wider range in mind. Details of this contention and supporting rationale will be presented in Section 3.5.

5.2.2.8. Conclusions from the SEITTP Concept vs. SEDIG Implementation Analysis

Given that the Group formed in, basically, an *ad hoc* fashion, but always with an eye toward providing systems engineering, development, and integration support to its sponsors, it should not be surprising that there is considerable overlap between its current implementation and the concepts and precepts brought forth in the original SEITTP concept document.

However, given that the original concept document addressed a far larger suite of possible activities, suitable for handling by a larger organization—the "Center of Excellence—it should similarly not be surprising that the current Group's activities focus on only subsets of the original concept.

Summarizing:

- **Education:** The Group's projects provide significant opportunity for students, although the opportunities could be increased if there were better integration with CoE faculty (see *Research*, following)
- **Research:** Owing largely to the limited areas of overlap between Group interests and those of CoE faculty in several departments that might otherwise be considered, research is not as broad as it could be.
- **Application:** The Group implements best practices, and provides the best balance between budget and application, using appropriate technologies to solve sponsors' problems.
- **WTI Positioning:** With its clearly rural focus, the Group has limited opportunity to address urban problems. This is further exacerbated by its geographical location.
- **Attracting Staff:** Due largely to its dependence on soft money and—to a certain extent—its geographical location, it is difficult to attract additional highly qualified staff.
- **Regional Infrastructure:** The Group is having significant success in several geographical areas, but may not be making the state and regional inroads that are hoped for.

Overall, then, the Group does what it does very well, but does not function at the level expected of a "center of excellence." Whether or not it is appropriate for the Group to move in such a

direction is subject to points raised in the next section, which offers several potential futures for the Group.

6. STAKEHOLDER PERSPECTIVES

An important part of reviewing the SEDI group's development, projects, and future directions was evaluating the group from the perspective of sponsors outside of WTI and the COE. A large number of the SEDI group's projects have been sponsored and championed by the California Department of Transportation (Caltrans). Notable partners include the Caltrans Division of Research & Innovation and Caltrans District 2. To maximize limited resources and still address the intent of Task 6, the project team chose to interview two individuals, one representing each organization. This section summarizes their responses.

Question 1: What (kind(s) of) project(s) have you worked on with WTI/SEDI group?

These stakeholders have worked on numerous projects with WTI generally and the SEDI group specifically and continue to be an active partner for many activities. For one stakeholder, all projects have dealt with rural ITS. Another has been part of a partnership with WTI for the past eight years and has become the project manager and/or project initiator for all rural ITS projects conducted in this partnership. The degree of involvement has varied from providing comments on a report or paper to providing input on tasks such as maintenance evaluations to acting as the project manager. Examples of current projects include the California Oregon Advanced Transportation Systems (COATS) series, the Western States Rural Transportation Technology Implementers Forum, One Stop Shop for Rural Traveler Information, Improve Communications Between TMC and TMS Elements in a Rural Environment Through a System that is Deployable Statewide, WeatherShare, Responder, Automated Safety Warning Controller, and Professional Capacity Building for Communication Systems.

Question 2: What is your overall impression of WTI generally, and the Systems Engineering Development and Integration group specifically? What are your perceptions of the Systems Group's activities?

The initial impression of WTI and the project work conducted by what would become the SEDI group, was somewhat negative. Projects had been awarded but were not necessarily headed the desired direction. Stakeholders agreed that frank discussions and the efforts of the program manager helped to "turn WTI around." Part of those efforts were hiring the right people and developing the current SEDI group. The current impression of WTI is a positive one overall and quality people and professionalism were mentioned specifically. One stakeholder comes from a rural district and thus appreciates the rural focus of WTI's research. He said that the rural focus is important, necessary, and appropriate. Another stakeholder commented that WTI and the SEDI group do "great work" and when his division shares work in progress, the majority is related to WTI and the SEDI group. While the interviewees had some exposure to other project work conducted by WTI, the majority of their interaction had been and continues to be with the SEDI group.

One stakeholder from Caltrans primarily deals with ITS projects and he felt the SEDI group was a natural fit with his work. He stated, "I've done a lot to try and support them," and specifically mentioned bringing lab equipment from Caltrans to WTI for the Automated Safety Warning Controller project. He also commented on the gratis work done by WTI to set up Caltrans' Rural Program Steering Committee. Another stakeholder commented that the COATS initiative and the Western States Rural Transportation Technology Implementers Forum have been well-received within his organization and other western states.

In general, the impression of the SEDI group and its activities was favorable and the group as a whole appears very capable. However, one stakeholder expressed concern about the potential for burnout and cautioned that while the group is strong now, an increased workload might cause people to "wear out" and ultimately leave WTI. The SEDI group should work towards developing an experienced staff to avoid project-based hiring. Additionally, he said a need exists to fill certain holes in the group's capability matrix. Applied system design, or practical construction of a system design, and manufacturing were two examples mentioned, though he recognized that the university environment was different from industry in terms of taking research projects through to the level of manufacturing.

The projects and topics that the SEDI group is exploring are appropriate. A stakeholder commented that departments of transportation are in need of more deployment opportunities for their research programs and that they shouldn't just pursue "pure theoretical research for research's sake." He said that more research funds should be spent on deployment. "There is more of a need and a focus that research dollars be spent on deployable things, whether that is products or procedures, that there is less emphasis from the DOTs and less funding, in fact almost no funding, for stuff that doesn't result in some kind of deployment." The SEDI group's work is a good example of this approach and current projects are definitely focused in the right direction. This stakeholder also mentioned that the group had improved since his last visit in addressing this focus, but more work needed to be done, including generating a commitment from WTI to support deployment efforts.

In addition, and maybe most importantly as it was strongly emphasized, WTI needs to understand that employee stability is a key and the commitment to that must come from the top. As one stakeholder has learned from personal experience, the ability to offer a stable and rewarding technical environment helps to improve longevity and stability among employees. He said "snatch up" good people when you see them, regardless of budget. "In order to build a successful team, to build the kind of people you need for that, you need to provide a rewarding technical environment with a high degree of stability," this stakeholder said. If the group has the capability, the work will come. Deliver excellent work every time and be cautious in what is promised. Do this consistently. He said the group will be successful with this approach.

Question 3: Do you think that the Systems Engineering Development and Integration program area at WTI could play a larger role in systems engineering and integration practices (e.g. nationally)? (How do you define Systems Engineering?)

Both stakeholders felt that the "classical" definition of systems engineering, either the spiral, "Vee," or staircase model, was the recognized standard in the transportation field. However, one stakeholder said that systems engineering at WTI was really a hybrid due to the nature of the research conducted. The SEDI group evaluates the methodology and does what works best for a particular project to best meet the end user's needs and requirements, and to develop a useful product. The other stakeholder further explained that a fundamental project goal is to design and implement technical systems for ITS that are fully integrated and meet the user requirements. He explained that from his perspective, the "Vee" model as used in transportation was really common sense engineering methodology and that good people would conduct their projects in a similar fashion regardless of a particular model or definition of systems engineering. While the procedure may not follow the particular model exactly, the outcome/results would be the same. He added, there are good people that "get it," meaning they understand the fundamental concepts and requirements of designing and implementing a quality system. In support of the SEDI

group's activities, he stated that the program manager "gets it", and reiterated that technical common sense is needed for successful project design and delivery,

Stakeholders generally agreed that the SEDI group could be playing a larger role (e.g., at the national level) in systems engineering and integration practices. Projects like Responder, WeatherShare, and One Stop Shop are good examples of applying the systems engineering process and developing a usable product. They certainly have applications to other states. A stakeholder further explained that the SEDI group should focus on research that results in a "useful product that is usable and deployable, robust and reliable."

One stakeholder commented that playing a role on the national stage could take the form of a Center of Excellence. However, such a center wouldn't necessarily guarantee successful influence on a national scale without qualified people who truly understand the purpose, goals, and applications of systems engineering. Again, he stated that it comes back to the people involved and having quality people who understand the goals and fundamental methodology required. "Engineering is still an art form," he said, and this is true for systems as well as equipment or mechanical engineering.

Question 4: Who or what organizations do you think could/would make use of the systems group's capabilities?

Other groups that could or would make use of the SEDI group's capabilities include other departments of transportation (DOTs) and public safety organizations. The Advanced Highway Maintenance and Construction Technology Research Center (AHMCT) at the University of California–Davis was noted as a natural potential partner and/or beneficiary of the SEDI group's capabilities. One stakeholder specifically mentioned western states' DOTs, and all DOTs surrounding Montana, including the Montana Department of Transportation (MDT). These states have large rural areas that could use systems like Responder, WeatherShare, or Automated Safety Warning Controller, for example. The stakeholder elaborated by commenting that using more of a building block approach, or developing common platforms, would push research further and the end result would be more deployed products. As an example, WTI is building a communications toolbox. AHMCT at UC Davis is developing a snowfighter application that gives snow and weather information to snowplow drivers and supervisors right in the cab. If the two groups collaborated, the end result could be a more "usable and deployable, robust and reliable" system that was more efficiently designed and deployed. The stakeholder added that because there is so much competition between organizations for the same funding that beneficial technology transfer (sharing) is not occurring as often as it could.

Local governments were also mentioned. This stakeholder explained that developing a government services integrator's function could be beneficial. Examples of what could be accomplished include facilitating smoother relationships between governments and schools or developing a system that makes it easy to build, contract, and get technologies to local governments. This could have broad applications not necessarily specific to transportation.

Question 5: Do you think the Systems Engineering program area could play a larger role in your work? How or why not?

One stakeholder immediately answered, "Absolutely!" That same stakeholder commented that he felt WTI and the SEDI group were often the only way to get products from the idea stage to the field; that WTI and the SEDI group understand real-world applications and are practical in

their research approach. However, the resources currently aren't available to award more and more projects to WTI. On the other hand, a research survey being conducted by other WTI researchers is gathering a large amount of information from Caltrans about potential future projects.

On this same note, concern over the stability of staffing within the SEDI group was reiterated. If more work comes in and additional staff is not hired, it's more likely that current SEDI group members would be overwhelmed and, consequently, the quality of work would diminish.

Question 6: How has the Systems Engineering Development and Integration group lived up to its mission to provide significant support to transportation technologies in the areas of:

- ***developing and integrating information technology and communications systems to meet end-user needs;***
- ***demonstrating systems engineering processes that leverage best practices to maximize limited resources;***
- ***analyzing and evaluating systems and alternatives to recognize capabilities and limitations and to maximize utility; and***
- ***raising awareness of systems engineering via workforce development and education at all levels.***

When asked how the SEDI group was working towards accomplishing that mission, the stakeholders listed a number of example projects. WeatherShare, Responder, and Improve Communications Between TMC and TMS Elements in a Rural Environment Through a System that is Deployable Statewide are good illustrations of "developing and integrating information technology and communications systems to meet end-use needs." Stakeholders said the SEDI group consistently completes steps common to various systems engineering models such as concepts of operations, requirements, risk analysis, and literature reviews. It was mentioned that the group tries to use system engineering processes that work best for a particular project to meet user needs rather than always following a particular model. In regard to analyzing and evaluating systems and alternatives, stakeholders said the SEDI group does this but is often under Caltrans direction and guidance. In other words, Caltrans gives the group ideas to consider based on customer needs. One stakeholder said the Western States Forum and the Professional Capacity Building for Communications project are two instances where the SEDI group is working to educate and develop the work force in regard to systems engineering processes. According to the stakeholders, WTI and the SEDI group are certainly active on the national level, and to some extent on the international level, through participation in groups and activities such as ITS America, World Congress, and the National Rural ITS conference.

Question 7: What are the strengths, weaknesses, opportunities, threats for the Systems Group? How do you think we should address weaknesses and threats? How should we leverage our strengths and opportunities?

As with the internal interviews conducted as part of this project, the stakeholders both described the program manager as a strength and cornerstone of the SEDI group. For example, software development done with his guidance has emphasized integration, which in one stakeholder's opinion was a key to systems engineering and rural ITS research. With that said, systems integration is also a strength of the SEDI group. The stakeholders thought the group had good

vision and technical common sense, the latter of which has already been mentioned in reference to defining quality systems engineering. The SEDI group is composed of highly intelligent individuals with compatible personalities that work well together and is generally a better team than it was in the past. The staff is eager to do a good job. The large student population available, from which to draw people who are willing to learn and take risks in a positive way, is another strength. Attention to detail, willingness to make changes to meet customer needs, understanding the mission of rural ITS, and a willingness to hold firm as needed were all mentioned as strengths of the SEDI group. One stakeholder underscored strengths by observing that the SEDI group and WTI provide an excellent value for the resources expended.

The stability of employment in a rewarding technical environment was one of the critical weaknesses identified. Sustaining core staff while maintaining the flexibility to expand and contract is a key concern for the SEDI group. According to both stakeholders, commitment and recognition from the top, the overall size of the group, and key anchor positions are considerations for addressing this weakness. The program manager should be guiding the execution of the research and focusing on growing the group, both in personnel and scope of work. If, instead, the group is struggling to maintain identity and taking on projects wherever funding is available, the focus on rural ITS could be lost, one stakeholder opined. The stakeholders commented that this in turn underscores the need for an individual with dedicated time for identifying, applying for, and ultimately bringing in potential work opportunities, both for the SEDI group and WTI as a whole. The idea of moving to more sustainable funding rather than project-based funding was also mentioned, although the stakeholder was unsure of the level of interest in attempting such a shift. For WTI as a whole, as projects and products are successfully deployed, the stakeholders indicated that a question also remains as to how to support those projects into the future.

One opportunity immediately identified by a stakeholder was that Caltrans has moved to project-based funding so that once a project has been approved the funding for all subsequent tasks is in place. This provides more stability for WTI and the SEDI group. Taking projects like Responder, WeatherShare, Automated Safety Warning Controller, and Professional Capacity Building for Communications to the national level is a great opportunity for the SEDI group. Projects such as the Federal Aviation Administration Center of Excellence, which is being pursued by another focus group at WTI, could move the organization away from ground-based rural ITS, but in turn bring more stability one stakeholder said.

The primary opportunity identified by another stakeholder was the "absolutely critical" need to figure out how to turn prototypes into manufacturable products. This involves developing procurable specifications. Once these are developed, the specifications can be given to a department of transportation for procurement and then deployment. The stakeholder further emphasized that this has not been done anywhere, and that the group that solves this problem will find great opportunities available.

The main threat discussed echoes a common theme—funding sustainability and the role of the current program manager. Stakeholders said that a threat exists for overloading the program manager and key staff. One stakeholder commented that people are going to leave, with the end result being a "paper organization with no deployable assets." Sustainable funding versus project-based funding for key staff and hiring a full-time opportunity seeker were suggestions for addressing this threat.

The importance of marketing to the right people in order to further leverage strengths and opportunities was reiterated. One stakeholder commented, "MSU needs to understand what an asset the systems group is." As another example of the importance of marketing, this stakeholder commented that WTI would be completely "invisible" to his division if it weren't for his and his colleague's continual efforts to demonstrate and discuss the work being done by WTI and the SEDI group. He said that WTI, and particularly the SEDI group, need to work hard at getting the message out about capabilities, the quality work being accomplished, and the comparative value of the research dollars invested.

Question 8: General: What are your perceptions of the Systems Group—strengths, weaknesses, activities, focus? How can we fulfill our mission (see above). What would you be interested in having us work on?

Stakeholders indicated that WTI and especially the SEDI group need a clear vision of the future for continued success. One stakeholder asked, "Where do you want to be in five years?" As a word of caution, he said maintaining this focus will be challenging because there will certainly be pressure to take projects that don't necessarily further the SEDI group's mission and goals. He continued, as relative "adolescents in the field of rural ITS," strong training and continued development of the attitude and rigor needed to compete and produce quality, useful, deployable products are critical for the SEDI group. A manufacturing center of excellence, or other means of supporting projects created by the SEDI group, will have to be part of the vision for the future of the SEDI group, one stakeholder thought. As a piece of constructive criticism, it was mentioned that the SEDI group needs to be more assertive with MSU to get what is needed to conduct operations and research. An attitude of "This is what we need to get this done, period," coupled with time and constant pressure was suggested. Examples cited were the communications pole, key access, and an equipment room for the TMC/TRAIL lab.

Other general comments and potential projects:

- Continue with product integration work;
- Revamp the Rural Work Zone project;
- Build own open systems RWIS;
- Run-away truck ramp system;
- New controller for changeable message signs, minor retrofits that will keep the old signs going while increasing the maintainability, operational effectiveness, and lifespan;
- One Stop Shop for rural public transit;
- Open source animal detection.

7. NEXT STEPS FOR THE PROGRAM

In addition to documenting WTI's experience in developing and implementing a systems engineering approach to transportation research, a primary objective of this project was to outline a future vision for the SEDI program area. To thoughtfully determine possible future directions for the SEDI group, the project team considered a number of different aspects of what that future might be.

As part of the *View from the Inside* (*Task 4*) and subsequent analysis (*Task 5: Independent view from the outside*), the independent consultant described several potential future directions for the group. Section 7.1 presents his ideas verbatim, as well as the relevant concluding remarks for *Task 5*. See Appendix C for more information.

The WTI Research Advisory Council meets annually to discuss the status of research and the course of future work. Section 7.2 includes the research directions for the SEDI group as recently presented by the program manager.

As mentioned previously, the SEDI group participated in the marketing effort recently organized for WTI by an outside marketing firm. This included establishing a number of programmatic goals. The goals are explained and included in Section 7.3 as originally submitted to the marketing firm.

Section 7.4 uses the ideas gathered from the project tasks to create an outline of potential future directions for the SEDI group.

7.1. Potential Futures

Note: This section (7.1) is taken from the independent consultant's report WTI Center of Excellence Feasibility Study Phase 2 (Tasks 4, 5). For the complete report, see Appendix C.

Future possibilities for WTI's Systems Engineering, Development, and Integration Group depend on the need for high-level decisions concerning the vision the WTI and College of Engineering administrations have for the Group. The task is further complicated by the observation that the role of the Group is still—as it was early on in the SEITTP feasibility study process—open to interpretation. In this latter regard, it must be decided if the Group is worthy of being a separate program (or focus area), or if it is to serve a support role for the other initiatives. Whichever direction is chosen, there will be budgetary consequences. If it is to further grow and develop as a separate initiative, then a means for securing its financing is necessary, as the constant search for soft money is sapping some of the strength of the Group. Even if it is relegated to a purely support role, then funds to engage its resources must be obtained by the other program areas, if only to have a fund and budget number against which the Group can charge for its support.

More than this, however, is the question of where the technical focus of the group should be. As currently constituted, it is almost (but not entirely) IT- and communications-centric. As noted earlier, given DoT's traditional evaluation of SE/I as being IT focused and the Group leader's own IT and communications focus, this is a natural outgrowth of its origins and the work it has been able to draw in since its inception. But, as noted earlier, there are many in the larger technical community who see SE/I as having applications far wider than information technologies, no matter how advanced they may be.

Another related area that should be addressed is the prospect of providing more than prototypes as solutions. Several respondents noted that sponsors often seem to want more than the prototype; they want fully fieldable solutions. To provide this requires that a manufacturer be found to produce often small runs of field-tested and proven solutions. Currently, the Group has no such connections, nor does it take into account manufacturing requirements in its designs—requirements that could dictate solutions other than those that result in prototypes. Regardless of what direction the Group moves, this kind of connection and insertion of manufacturing requirements should play a larger role if the Group is to be maximally responsive to a wider range of constituencies. The program manager is aware of the increasing importance of such an approach to sponsors, and argues that such a move is a natural evolutionary next step, in that sponsors' early requirements emphasized prototype generation. This is an issue in a state of flux, and the subject of discussions within WTI generally.

Keeping this requirement in mind, herewith are presented several possible scenarios for possible futures for the Group, all of which should incorporate the manufacturing boundary conditions. The options presented here are offered as indicative of possible futures. Please note that no opinion is provided as to which is the "best" direction for the Group. Rather, more input from higher-level strategic planning activities is needed before a specific recommendation could be made.

7.1.1. Basic Option I: More of the Same

Given the clear success of the Group in addressing primarily IT-type projects for its sponsors, continuing along the current trajectory is an easy path to follow. This is not to minimize the difficulties that lay ahead of the Group: The lack of more-senior staff, limited financial and human resources, and the heavy reliance on the program manager will continue to be problematical. Such problems would be fewer than those associated with the other options to be discussed below, but maintaining the IT focus, depending on existing sponsors, and maintaining a low level of participation with COE faculty is a relatively safe place to be.

Assuming the acquisition of additional work within this framework, the ongoing, well-earned success of the Group would likely continue, but this option does not allow for much further growth or development.

7.1.2. Basic Option II: Expanding Breadth

A slight variant of the status quo that could generate more work (and associated funding) is to attempt to find additional sponsors. The more sponsors there are, the more financial resources would be available, thereby allowing the size of the team to increase. Under narrow but plausible conditions, the additional funding could also allow more senior staff to be hired, along with a co- or deputy program manager to help the program manager by offloading some of the management and technical work, including the need for written and oral communications. To a first approximation, additional sponsors could come from any organization—from the local, state, and regional levels through national and, conceivably, international groups that deal with transportation.

7.1.2.1. Center of Excellence in SE&I (IT only)

Mooted in early presentations to the COE faculty and associated planning documents was the concept of a "Center of Excellence" in SE/I, emphatically with emphasis on IT, as that is how the transportation community views SE/I. This direction is a natural evolution of expanding the breadth of the existing group.

As currently constituted, formation of such a Center seems unlikely, owing to the relative professional immaturity of the Group's staff and the other limitations described elsewhere, the group's obvious successes and relatively unique expertise in rural applications notwithstanding.

Implicit in the concept of a Center of Excellence is a core group of professionals with significant experience and applicable expertise, around which would coalesce several concentric rings of interested parties, and extensions out into a very widely ranging community. Often explicit in universities' (and agencies') criteria for Center of Excellence status is a heavy emphasis on research, both basic and applied. The current Group does a fine job with finding or inventing solutions, but is not at all well-placed to push the edge of the envelope in new SE/I processes and procedures, nor in communicating either its current practices or potential new ones to a wider community, the program manager's efforts to do this notwithstanding. Some of this could be mitigated by tighter integration with and participation of COE faculty, both as to larger numbers of faculty from departments already working with the Group, and a larger number of departments similarly involved.

Further, some source of funding would be required that would move the Group out of its current stultifying dependence on soft money. Herein lies a Catch-22: To attract programmatic funding would require that there be a hard-core cadre of staff (with a heavy emphasis on senior practitioners), capable of doing both basic and applied research, and a portfolio of successful projects that clearly shows that a large(r) Center-sized group can acquire and handle such projects. On the other hand, such a group cannot be formed without significant programmatic funding.

Regardless, were it practical to form such a center, the many laudatory sample projects outlined in the original SEITTP concept document would be well within reach, with concomitant potential to grow a center of excellence in the directions summarily discussed in Section 7.1.3, below, depending on the time horizon applied to this strategic planning activity. A consequence of such positioning is that the opportunities for attracting additional work from a more varied number of potential customers increases significantly.

7.1.2.1.1. Possibilities for Other Center Types

The statements above apply also to the possibilities that had been raised in the original SEITTP concept for the formation of an Engineering Research Center (ERC) or the organization of an Integrative Graduate Engineering and Research Training (IGERT) group, but the strictures are even more constraining when attempting to generate a competitive proposal for their cognate programs.

Both ERCs and IGERTs call for significant integration of capabilities provided by their supporting organizations, i.e., the location of the center itself, supporting organizations, etc.; clearly defined research programs (usually with an emphasis on basic research, but applied is not unknown); integration of research areas with established and new or to-be-developed curricula; novel means of management across the various disparate entities; clear informal education and

outreach plans; plans for attracting underrepresented minorities; and more. Given the current track record with respect to engaging solely with a limited number of COE representatives in a small number of departments; the remoteness of WTI and the attendant potential difficulty in attracting additional stellar and minority professionals and students; and the lack of any evidence of curricular integration (i.e., hands-on work augmented by specific formal coursework (or vice versa)), ERC and/or IGERT formation seems a remote possibility.

7.1.3. Advanced Option: New Directions

As noted earlier, how one defines SE/I depends upon where one is accustomed working. For those with a transportation focus, and decidedly those within the current Group and the WTI executive director, this explicitly means IT and communications centrism. For almost everyone else, however, SE/I has a wider range of applicability. It is clear that the tools and approaches as currently implemented in the Group are appropriate and used to best advantage in the IT arena.

However, by expanding the breadth of activity (i.e., IT focus, but with more clients, now both within and outside of the transportation community), and by developing and expanding the depth of the Group's activities (i.e., developing more and better tools, processes, and procedures for SE/I across many foci in the solution space) takes the Group and WTI in entirely new directions, fraught with uncertainties and with significant competition from established groups, both within and outside of the transportation realm.

It is important to note that virtually every interviewee saw benefits in moving the Group's activities beyond the IT and communications realm, and were excited by the possibilities. But they also saw the difficulties in moving beyond IT, as that is where the current focus is, both for them and their own areas of expertise, and the emphasis being put on the types of projects being made available to them by current sponsors.

7.1.3.1. IT- and Communications-specificity vs. SE&I Generally

As has been mentioned several times in this document, applying SE/I processes and procedures is not necessarily limited to the IT and communications domains. While it has significant utility there and, as such, of particular application to transportation problems and their solutions, many (if not most) engineers do not see IT and/or communications as the prime foci. Indeed, SE/I can—and should—be thought of as a generalizable set of tools that can be applied to any system, which includes systems of systems.

By making this kind of conceptual leap, one may easily see that problems may be attacked in a holistic fashion, one that is far more encompassing than the IT- and communications-centric focus as practiced by the current Group. Such systems can become huge—almost intractable—but it is then up to the systems engineers to work tightly with clients/customers to define the limits thereof, and then to apply best practices across a wide range of disciplines to integrate suitable technologies and approaches to develop tractable, affordable, applicable, and—one hopes—expandable systems that are responsive to the original problems. Such responses cannot be thought of as complete end-points. Rather, they must be designed in such a way as to allow further growth and development, building on those initial (and follow-on) solutions.

To do this in any reasonably disciplined fashion requires input from many different areas of expertise, beginning at the requirements-gathering and -definition stages of SE. The kinds of problems that could be addressed by this widely cast net approach becomes far larger than even

the largest IT- and communications-centric problems. There is clearly still a role for IT and communications in solutions for many of these problems, but it becomes only a part, rather than the whole.

Such an approach fits well with the COE's approach to training the future workforce, as outlined in the Summer 2007 "Message from the Dean" (http://www.coe.montana.edu/message_from_dean.html), wherein Dean Marley refers to the National Academy of Engineers concept of the "engineer of 2020", and MSU's response as the "MSU Engineer of 2010". This concept emphasizes multidisciplinary design and—as practiced by other universities, the need to create the "multi-dimensional engineer" or "trans-disciplinary engineer", resulting in the Boeing Corporation concept that they expect their engineers to be "systems integrators". As Dean Marley said, "In general, this means that they better understand the business environment, technical trade-offs in complex product or system design, and even that they appreciate entrepreneurship."

7.1.3.1.1. Center of Excellence in SE&I (All systems)

These same precepts and approaches can (and should) be applied to the Group in whatever incarnation is ultimately deemed optimal, to the benefit of the Group and, ultimately, to its clients. But it is in the realm of a holistic, cross-system approach to the implementation and application of SE/I principles and processes that its true value comes to the fore.

With such a widened mandate, the Group's growth into a true Center of Excellence in SE/I absolutely requires a strong team of multi-, inter-, and cross-disciplinary engineering solutions to problems. The opportunities for such teams to cross-pollinate its members would clearly increase the value of the individual for future work, regardless of the discipline, or the professional level. Everyone, from students onward, would continue to learn and increase their skill set, not only in technical areas, but in ways that would accommodate Dean Marley's admonition to understand business, have a wider view of potential solutions, and open doors for entrepreneurial activities.

There are many issues that must be dealt with in approaching such a goal. There must be significant buy-in on the part of many faculty members across many COE faculty (and, likely, those from other colleges within MSU) to develop research programs and curricula that are directly responsive to such a mandate. New and creative methods of teaching and optimizing organizational dynamics across many stakeholders must be developed and implemented. Further, inroads must be made with high-quality organizations in the private sector to further leaven the mix.

Programmatic funding is a *sine qua non* of any such organization.

The challenges facing the Group specifically, and WTI and the University generally, also include the current make-up of the group, whose focus is—owing to the way the Group was formed, how it developed, and how it has been led—clearly in the IT camp. It is possible that the program manager (whose experience is in CS and IT, and who has shown definite expertise in SE/I in this area) has the wherewithal to lead an organization with such a broadened scope. Were this to be the case, it is increasingly imperative that some new form of management structure be implemented, as the program manager is already suffering from the number of responsibilities he manages.

From a more distant perspective, the question must be asked, would such a center fit under the general rubric of WTI? Or, is this something that the University would want to establish as a separate organization, one that would tap a SEDI Group within WTI, whose core competencies would remain IT-centric and transportation-focused?

7.1.4. Concluding Remarks, Task 5

7.1.4.1. "Center of Excellence" Philosophy

The original SEITTP study had as a prime focus the prospect of developing a "center of excellence" in systems engineering and integration as applied to transportation issues. The information elicited in Task 4 and the analysis of possible futures for the Group, as embodied in Task 5, have brought several issues to the fore. These issues reduce to several easy-to-ask questions.

1. Should the group keep its current size and make-up, continuing to service its current core sponsorship?
2. Should the group expand its size and make-up as a means of expanding its customer base, but still within the transportation rubric?
3. Should the group broaden and deepen its make-up in an effort to attract customers/sponsors outside the transportation realm?
4. Should the group develop a stronger, more academic research profile, necessary to organize a true "center of excellence" in systems engineering and integration?

Distributed across all these questions is a key question, the response to which will depend on which route is chosen:

Where is the most help needed (i.e., technical; management; development)?

The answers are not as easy to develop.

A distinction that may help in making such decisions is the difference between science and engineering.

Science in this context is meant to describe an approach to a discipline that emphasizes asking basic questions, albeit with an eye toward ultimately applying new knowledge that arises from such activities.

Engineering in this context is meant to describe a suite of activities that is eminently applied to solving specific problems, albeit with a lessons-learned component that would allow generalizing approaches across a wide range of problems. There is definitely a research component to engineering, but it is applied research, i.e., problem-specific.

If a true "center of excellence" is the desired target, then there must be a "scientific" component, one that—by design—furthers the disciplines of systems engineering, looking for newer and better ways to define and understand user requirements, and to translate them into workable solutions. It also means developing new and better ways to allow optimum integration of components into those solutions. This hearkens back to the earlier discussion of, "What are 'best practices'?" This, in turn, entails research into the nature of such practices, and developing metrics to clearly define "best".

The results of such "basic" research would then be integrated into the applied arm of the center, with concomitant feedback between the two arms, such that the theories developed in the "science" arm are applied in the "engineering" arm, and the results of those applications fed back to the "science" arm. This process is the essence of systems engineering and integration. The ability to successfully apply such tools to the activities of the organization itself is, perhaps, the best metric, as it should result in a positive feedback loop, one that generates more and more-satisfied customers.

WTI and the COE may be in a position to accomplish this, but it would require that the Group broaden its activities outside the IT and communications realm, although the focus of the center could remain in transportation, with one caveat: The principles and processes that would be developed in such a center would have significant generalizability, and could allow for growth into areas outside transportation issues. This, then, requires significant consideration on the part of the university of exactly what it wants such a center to accomplish, and how it would fit into the university's larger strategic mission.

7.1.4.2. Philosophy in Practice

The exposition of the preceding section aside, it is very clear that the Group as currently implemented performs admirably. Its internal and external interfaces and activities are providing significant service to its sponsors, and the members are highly respected by their peers and their customers.

The Group's activities are clearly in keeping with the basic tenets of the original SEITTP concept, differing only in terms of scope and range of potential activities. The members are consummate professionals with a combined broad range of expertise and experience that are brought to bear with a sterling track record of satisfying their sponsors, employing best practices throughout their activities.

As noted above, while it is this writer's opinion that without significant focus and structural changes the Group is likely not well positioned to be a true "center of excellence" in SE/I, they could grow and form an increasingly viable, visible, and valuable focus (i.e., "center", in a general sense) for practical SE/I activities generally, providing education and assistance to the transportation community and, potentially, to an even wider range of interested groups.

7.2. Research Directions

The following topics are currently being studied at various levels and/or represent possible directions of interest for the SEDI group:

- Data Communication for ITS and Public Safety in General
    - Traditional RF
    - New RF (WiMax, Mesh, Mobile Ad-Hoc Networks, etc.)
    - Dedicated Short Range Communications (DSRC)
    - Communication System Design and Analysis
- Data Collection
    - Automated

  - Manual w/ Technology (Responder, Roadkill Observation Collection System)
- Data Aggregation & Dissemination and Open, Re-usable Distribution of Data
  - Web 2.0
  - RSS, Blogs, etc.
  - The "Long Tail"
  - California Oregon Advanced Transportation Systems-related
- Next Generation Traveler Information
  - Location Awareness
  - Situation Awareness
  - User Awareness (customized per individual preferences and needs)
  - Multiple Outlets: In-Vehicle, Kiosk, Traditional Web, Web 2.0, Mobile Devices (Smartphone)
- Visualization (for the masses)
  - Google Earth
  - WWW
- Sensor Technologies and Networks / Robotics
  - Zigbee, etc. (802.15.4)
- Vehicle Infrastructure Integration
  - DSRC
  - Non-DSRC – Cellular and other (WiMax, 3G/4G)
  - 802.11p (WAVE – Wireless Access for the Vehicular Environment)
  - Applications
- Use & Utility – User Interface Design
  - Responder (Tablet PC)
  - Speech and other Alternate Interfaces
- Open (Source) Models for Software Development and Dissemination and Hardware Platforms
  - Following the emerging trend in software.
- Artificial Intelligence & Traditional Computer Science Including Image Processing, Optimization
  - Example: Ant Colony Optimization
- Advanced Technology Training / Professional Capacity Building
- Process Models

- Systems Engineering
- Software Development for Transportation

7.3. Goals

In the summer of 2008, WTI began working with the marketing firm of O'Berry Cavanaugh. As part of the overall marketing plan for WTI, each program area submitted two to five goals for each of six different marketing themes—reputation-building, networking, publishing, cross-fertilization, presentation, and media outreach. Timelines and success criteria were established for each goal. The SEDI group's goals as written for this marketing effort are outlined below. Included is an explanation from the marketing firm on how to interpret each theme.

7.3.1. General Goals for the Systems Group

1. Develop, conduct, and support demonstrations. Includes both onsite (lab) and offsite demonstrations.
2. Attend and conduct conferences. Develop and conduct presentations at conferences.
3. Develop group capability portfolios—include project experience and staff capability.
4. Train staff to do program area marketing. Promote marketing capabilities within the organization (WTI).
5. Identify funding opportunities. Secure funding.
6. Improve marketing to MDT and other DOT.

7.3.2. Reputation-Building Goals

Reputation-building includes anything that helps you build a reputation as a thought leader in your specific research area. It should go above and beyond the usual publishing and presenting on existing research—ideally it allows you to convey a point of view, an opinion, or pose a provocative idea. Ideas might include writing and sending e-newsflashes, blogging on WTI's website, or successfully drawing attention to a particular research gap or need.

Goal No. 1:

The Systems Engineering Development and Integration group will develop and conduct five or more project and/or technology demonstrations by 2010. (Ideally, all projects will have associated demonstrations.) These demonstrations will show realistic and practical applications of cutting-edge ITS technologies, demonstrating how "cutting/bleeding edge can meet the practical." They will demonstrate how the group can solve rural transportation problems using appropriate technology. The group will work to establish a stable means of supporting this goal with financial, physical, and human resources. The demonstrations will be "re-usable" and applicable for both onsite and offsite demonstrations.

Demonstrations:

1. Mesh networks; August 14, 2008; Hot Springs County, WY
2. ROCS=Roadkill Observation Collection System
3. Responder
4. WeatherShare
5. TRAIL & Trailers

To be accomplished by: July 2010

Success criteria:

a. Whether each demonstration has been developed and conducted by 2010.

b. An account set up and dedicated to developing and conducting the above demonstrations.

c. Demonstrations will show realistic and practical applications of cutting-edge ITS technologies that address rural transportation challenges.

d. Demonstrations will be conducted both onsite and offsite.

Goal No. 2:

By 2010, the Systems Engineering Development and Integration group will develop professional and project capability portfolios that clearly explain the rural transportation challenge the project addresses, demonstrates how the project uses technology to solve the problems presented, and will be a tangible resource for rural transportation professionals. The group will work closely with the WTI communications group to develop the portfolios. Portfolios may include testimonials, where appropriate and feasible.

To be accomplished by: July 2010

Success criteria

a. Whether each project being conducted by the group has an appropriate project capability portfolio.

b. Portfolios will consist of a combination of print, web-based, video, and interactive materials beyond the traditional fact sheets and web descriptions. Portfolios may be accompanied by corresponding demonstrations from Goal No. 1.

7.3.3. Networking Goals

Much of WTI's funding comes through existing contacts in the field. Whether you consider yourself a "people" person or not, it helps to know people in the right places. Networking goals should challenge you to get your name/research into the right hands—these goals should be as specific as possible, down to the name of a person or an organization you'd like to get to know. They can also include joining boards, journal review committees, or social networks that are likely to yield good contacts in the field.

Active networking will benefit the SEDI group by recruiting excellent students, bringing in an increased number of projects, enhancing project work through collaboration, and allowing the group to delve into topics that are interesting, relevant, and cutting edge. Included in this activity will be pro-active searches for funding opportunities.

Goal No. 1:

Goal No. 1a: Each semester until the summer of 2010, the Systems Engineering Development and Integration group will work with the MSU College of Engineering faculty to identify relevant and practical rural transportation topics, and then develop and present two guest lectures to the appropriate classes or seminars. At least one of every three guest lectures will be in a class outside the Computer Science and Electrical Engineering disciplines.

Goal No. 1b: Over the next two years, the Systems Engineering Development and Integration group will give three presentations to different MSU groups/disciplines outside the COE. The

group will work closely with other WTI program managers, Jerry Stephens, Susan Gallagher, and Robert Marley (Dean of the COE), to identify opportunities, and then develop and conduct a presentation.

Goal No. 1c: Each year until 2010, the Systems Engineering Development and Integration group will prepare and conduct one presentation to a public organization (e.g., Rotary International, Kiwanis) concerning a timely and relevant rural transportation topic. Presentations will highlight and explain the work of the SEDI group and WTI on the chosen topic.

To be accomplished by: July 2010

Success criteria

a. Whether the indicated number of presentations has been conducted.

b. Whether funding has been allocated to support such efforts.

Goal No. 2:

By 2010, the program manager will be serving on at least one nationally recognized committee or forum. At least one other group member will be serving on a local, state, regional, or national committee or forum addressing some aspect of rural transportation. Adequate financial and human resources will be in place to allow him and/or her to serve without causing undue pressure on the individual, the group, or project work. ("Adequate financial and human resources" will be defined when the individual considers the service opportunity.) Opportunities include Transportation Research Board, National Rural ITS conference, ITSA, ITS World Congress, IEEE and ACM.

To be accomplished by: July 2010

Success criteria

a. Whether the Program Manager is serving on a nationally recognized committee or forum.

b. Whether another group member is serving on a local, state, regional, or national committee or forum addressing some aspect of rural transportation.

c. Whether adequate funds for each individual are designated to support the time and expense required to fulfill the committee or forum responsibilities.

Goal No. 3:

By 2010, the Systems Engineering Development and Integration group will be collaborating on at least one project with each of the following different entities: Department of Homeland Security (DHS)/Department of Justice (DOJ); local, state, federal or international public safety group; Montana Department of Transportation (MDT). A MSU COE researcher and/or other MSU researcher, will be involved in the majority of new projects.

To be accomplished by: July 2010

Success criteria

a. Whether at least one, but ideally more, projects started after the current date (July 2008) are collaborative with DHS/DOJ, public safety groups, and MDT.

b. Whether each new projects started after July 2008 involves collaboration with a researcher(s) within the MSU COE and/or another MSU discipline.

Goal No. 4:

By 2010, the Systems Engineering Development and Integration group will have established a working relationship with at least two private-sector companies (i.e., Google, Microsoft, Motorola).

To be accomplished by: July 2010

Success criteria

a. Whether relationships are established with two private sector companies as defined above.

b. Attendance at associated tradeshow or similar event targeted at specific companies.

Goal No. 5:

By 2010, the Systems Engineering Development and Integration group will have established as routine practice pro-active searches for funding opportunities.

To be accomplished by: July 2010

Success criteria

a. Identification of online and other sources of funding opportunities best suited for program.

b. Routine use (weekly) of sources.

c. Identification of five or more funding opportunities for three or more prospective PIs within the program.

d. Proposals written for three funding opportunities.

e. Funding secured for two funding opportunities.

7.3.4. Publishing Goals

What journals or other publications would you like to target for publications? How many publications would you like to place in between 2008 and 2010? How can you further disseminate published results (i.e., WTI website, e-newsflashes, conferences, etc.)?

Goal No. 1:

Within the next two years, the Systems Engineering Development and Integration group will have published and/or presented (published in conference proceedings) in the following venues: Transportation Research Board, National Rural ITS conference, ITS America, ITS World Congress, Institute of Electrical and Electronics Engineers (IEEE), and the Association for Computing Machinery (ACM).

To be accomplished by: July 2010

Success criteria

a. Whether papers and/or posters have been accepted and/or published in the journals or conference proceedings listed above.

b. Publication of scientific papers, in addition to technical papers.

Goal No. 2:

By the end of this year, the Systems Engineering Development and Integration group will design and implement more dynamic web pages that accurately portray group capabilities while facilitating access to the people and resources involved in projects of interest.

To be accomplished by: December 2008

Success criteria

a. Whether the Systems group and Laboratory web pages have been updated with dynamic project portfolios that include interactive demonstrations, video, descriptions, interesting links, and contact information.

b. Whether the WTI Website accurately reflects project work of the program.

Goal No. 3:

Within the next two years, the Systems Engineering Development and Integration group will implement a WIKI for both internal and external use in distributing documentation, source code and other intellectual property. Initially the WIKI will be for unidirectional communication, but ultimately it will enable bi-directional communication, allowing sponsors, stakeholders and others to contribute content.

To be accomplished by: July 2010

Success criteria

a. Whether the Systems Group WIKI has been enabled for internal communication

b. Whether the Systems Group WIKI has been enabled for external communication.

c. Whether the Systems Group WIKI has been enabled for input/contribution from sponsors, stakeholders, and others.

7.3.5. Cross-Fertilization Goals

Cross-fertilization is an important goal for WTI because very few sponsors have the opportunity to learn about or benefit from the expertise available at WTI in different program areas. Aside from the occasional project manager meeting, there are currently no formal procedures to encourage cross-fertilization of research projects within WTI. What kinds of things can you do to get to know other research areas, brainstorm ways to work together, and propose research ideas that utilize more than one program area?

Goal No. 1:

To develop program area and organization (WTI) marketing skills, the Systems Engineering Development and Integration group will have a "brown bag lunch" meeting once per month. Topics for discussion/dialogue/presentation at these meetings will be: project progress and next steps; project demonstrations; interesting topics for future research, how they fit within the program and WTI, and possible collaborators; ideas for group coordination; guest speakers (i.e., other program areas, MSU COE, sponsors; etc. Meeting agendas, or outlines, will be established two weeks in advance to allow for preparation and topic development.

To be accomplished by: July 2010

Success criteria

a. Whether monthly meetings are held.

b. Agendas are established promptly and reflect the interests and needs of the group.

Goal No. 2:

The Systems Engineering Development and Integration group will encourage more frequent and more regular all-staff meetings and program manager meetings. These meetings can also be "brown bag lunches" as above. All-staff meetings should provide a forum for a face-to-face "show and tell" during which different program areas can demonstrate an interesting part of their research. Dialogue should be held to discuss WTI positioning and rural transportation issues. All-staff meetings should be approximately 1 hour at most. Program manager meetings should discuss WTI organization strategies in addition to the above topics and should be 1 hour to 1 ½ hours at most.

To be accomplished by: July 2010

Success criteria

a. Whether meetings are held as described above.

Goal No. 3:

The Systems Engineering Development and Integration group will enable staff to do program area marketing, marketing not only their skills, but also the skills of the program. Portfolios and demonstrations will be key components of this capability. Staff will need to be "trained" to conduct such demonstrations so that on any given day, if a guest shows up at WTI, any given staff member will be able to market/demonstration/discuss the work of the program.

To be accomplished by: July 2010

Success criteria

a. Whether staff has access to the materials (portfolio and demonstrations).

b. Whether staff has been trained to use materials.

c. Whether staff has marketed program area.

7.3.6. Presentation Goals

Which conferences do you plan to attend in the next two years? Which ones would be ideal for making a presentation, making a poster, or just attending? What do you hope to get out of these conferences? Who would you like to meet at these conferences? Alternatively, are there any events, forums or conferences you would like WTI to host or establish?

Goal No. 1:

Members of the Systems Engineering Development and Integration group will attend the following conferences over the next two years: Transportation Research Board, National Rural ITS, ITS America, ITS World Congress, IEEE, ACM, Western States Rural Transportation Technology Implementers Forum. Papers, posters, presentations, and/or demonstrations will be submitted for consideration for each. (See Publishing Goals.)

To be accomplished by: 2010

Success criteria

a. Whether a member or members of the Systems group attended the above conferences.

b. Whether papers, posters, presentations, or demonstrations were accepted and presented at the above conferences.

c. Whether new projects and/or new funding opportunities were identified through networking opportunities.

Goal No. 2:

The Systems Engineering Development and Integration group will coordinate the annual Western States Rural Transportation Technology Implementers Forum.

To be accomplished by: June 2009, June 2010

Success criteria

a. Whether the Forum continues to grow and develop while still maintaining the original "flavor" and intent.

b. Whether next steps have been identified for the Forum – i.e., how to manage success.

7.3.7. Media Outreach Goals

What specific media outlets would you like to attract the attention of? Radio, TV, magazines, newspapers? Local, regional, national? What would you like the public to know about your work or what are you working on that is relevant to the general public?

Goal No. 1:

To enhance public awareness of WTI and the work of the Systems group in rural transportation, the Systems Engineering Development and Integration group will work with WTI communications staff and the MSU News Service to write and submit press releases and articles to state-wide newspapers that describe a project or activity and its impact on the public.

To be accomplished by: 2010

Success criteria

a. Whether five press releases are issued per year through MSU press.

b. Whether two articles per year are published in each of the following papers: Bozeman Daily Chronicle, Missoulian, Great Falls Tribune, Billings Gazette, Montana Standard, Independent Record, and other Montana newspapers.

7.4. Summary

In the transportation field, and particularly in rural transportation, there is a considerable need for advanced ITS technology and people to work with that technology through all phases of design and implementation. There are associated opportunities to work with departments of transportation and other public agencies (e.g., public safety organizations) to address the need through workforce development, establishment of best practices, and technology transfer.

To take advantage of the opportunities and continue to address the needs of rural transportation, the SEDI group must determine how best to leverage its skills, capabilities, and strengths, while

positively managing any weaknesses or threats. Outlined below are potential next steps for the SEDI group, as suggested by the findings of this project and in complement to those discussed by the independent consultant in section 7.1.

- First, it is clear the SEDI group is developing useful products with a methodology that demonstrates how the systems engineering process can be used to meet end-user needs practically and effectively. This process should be continued.
- Secondly, the SEDI group, WTI, the College of Engineering, and even MSU must reach a consensus and clear understanding of the group's vision, direction and focus, whether it is IT, communications, a wider perspective on systems engineering, level of technology support to other program areas, etc.
- Depending on the anticipated focus, the group may consider changing its name to something more closely representative of the group's activities.
- Repeatedly expressed was the importance of hiring and retaining qualified people with the skills and understanding of the work the group can and should be doing. This must be done pro-actively. Good people should be hired when the opportunity arises rather than waiting until they are needed for a particular project. Considerations to address include the pros and cons of the affiliation with MSU, the group's name, ability to offer a competitive wage, more sustainable funding (programmatic support) versus project ("soft money") funding, and geographic location.
- An individual staff member who is dedicated to seeking out and winning projects and funding would be a tremendous asset to not only the SEDI group, but WTI as a whole.
- A senior staff member should be hired to address the gaps in the SEDI group's capability matrix and relieve pressure on the program manager. This individual would ideally have a skill set complementary to the program manager, possess high-level communication skills, and have real-world work experience.
- A common theme deemed crucial for the SEDI group is developing a manufacturing component that can take the group's work beyond prototypes to actual procurable and deployable products.
- As affiliates of a university, WTI and the SEDI group are poised to be natural leaders at the forefront of professional capacity building for ITS technology.
- Successful projects are increasingly multi-disciplinary. The SEDI group should continue to collaborate meaningfully with other disciplines, most notably with other program areas within WTI and different departments within the COE.
- As shown in Table 1, a large number of SEDI group projects have Caltrans partners and/or are sponsored by Caltrans, particularly the Caltrans Division of Research and Innovation and Caltrans District 2. This is indicative of the strong, positive working relationship that the program manager and the SEDI group have worked hard to cultivate and maintain. It would be beneficial to continue and further expand this relationship to other Caltrans districts. In addition, several of the projects that have started in Northern California have since expanded to cover the entire state. Some, like WeatherShare,

Responder, One-Stop Shop, and Integrated Corridor Management could be adapted and applied to other rural areas in different states and used by other public safety agencies.

- To help diversify partners and funding, the SEDI group should consider a targeted marketing effort that focuses on the group's strength in technology applications. In other words, the group might market its capabilities through continued high quality work with more visibility on the World Wide Web and a few key demonstrations, presentations and/or paper submissions to appropriate, key venues. Development of capability portfolios would be an important asset to this effort. Service with relevant national, or even international, committees and forums could also help to market the group's capabilities and ultimately assist in bringing in additional projects and partners.
- The group should continue to work towards accomplishing the goals presented in section 7.3. To keep the SEDI group moving forward, additional goals should be established as earlier ones are successfully reached.

8. CONCLUSIONS

The parent project (Phase 1) examined the feasibility of developing a systems engineering and integration program that could better address the challenges of rural transportation, with potential application on a broader scale. It included developing a mission statement, outlining focus areas, compiling a list of potential usage scenarios, ascertaining internal and external capabilities, assessing needs, and identifying potential stakeholders, competitors, and funding sources. Phase 2 was designed to compare this original concept with the development and status of the current SEDI program area, with the goal of outlining how the group should proceed from this point forward.

Based on the input from internal and external stakeholders and the perspective from an outside expert unaffiliated with WTI, it can be concluded that the SEDI group has evolved in line with the transportation industry's perspective on systems engineering and the unique challenges presented by transportation in rural areas. Quality work that meets the needs of end-users in a practical, cost-effective manner is being accomplished within the constraints of available human and monetary resources. The SEDI group is meeting the basic tenets and overall goals of the original concept, though the scope and breadth of its current activities differ.

In large part, the current work of the SEDI group is focused on IT and communications, a base aligned with the transportation industry's definition of systems engineering, the group's expertise, and work available through current sponsors. As articulated by the independent consultant, maintaining the status quo is a safe place to be as an organization. With that said, many stakeholders saw benefit and expressed interest in the possibilities of expanding the SEDI group's work to a wider definition of systems engineering with a greater breadth and depth of research activities.

A number of the next steps listed in section 7 can be accomplished in the near term. Looking towards the future, the decision to remain as is, expand the client base within the transportation IT and communications realm, or move outside transportation even to the status of a systems engineering "center of excellence," will ultimately require further strategic planning and is beyond the scope of this project. However, the information and perspectives gathered over the course of Phase 1 and Phase 2 of the SEITTP feasibility study provide a solid foundation from which to make this decision and ultimately guide the SEDI group towards continued success.

9. REFERENCES

1. Galarus, D. 2004. *WTI systems engineering and integration of transportation technology (SEITTP) program concept document DRAFT*. Bozeman, MT: Western Transportation Institute, College of Engineering, Montana State University–Bozeman. Internal document.
2. International Council of Systems Engineering, www.incose.org/practice/whatissystemseng.aspx. (Last accessed November 8, 2007).
3. Western Transportation Institute. 2006. *University Transportation Center strategic plan.* Bozeman, MT: Western Transportation Institute, College of Engineering, Montana State University–-Bozeman.
4. Clark, A., Garmire, E., Williams, K., and Hunt, A. 2003. *AAAS review of materials science programs at Montana State University: Final report of the external review team.* Internal document received from Lee Spangler, Director of Special Programs, Vice President for Research Office, Montana State University–Bozeman.

10.APPENDIX A—WTI SYSTEMS ENGINEERING AND INTEGRATION OF TRANSPORTATION TECHNOLOGY PROGRAM (SEITTP) CONCEPT DOCUMENT

WTI Systems Engineering and Integration of Transportation Technology Program (SEITTP) Concept Document

by

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WTI Systems Engineering and Integration of Transportation Technology Program (SEITTP) Concept Document

OVERVIEW

The objective of this study is to determine the feasibility of creating a Systems Engineering and Integration of Transportation Technology Program (SEITTP) within the Western Transportation Institute at Montana State University. The proposed program will be dedicated to defining, developing, promoting and applying an integrated and interdisciplinary approach in all aspects of complex and innovative transportation technologies including specification, design, training, integration, deployment, operation, maintenance, and evaluation.

This document, the concept document, is the compilation of information gathered from MSU COE faculty, WTI staff, and a subcontractor, Shel Leader. Initial text was taken from presentations and drafts created by Steve Albert. Feedback was provided by the people mentioned above, to assist in defining a clear, agreed-upon concept of the potential program. One changes of particular note was changing the name from "Center" to "Program." There was expressed uncertainty regarding the relationship of this proposed entity with WTI. Calling it a program within WTI clarifies that issue. Other comments were made asking if the focus would be rural or general (rural and urban), or if there would be a national or regional focus. Tentatively, these have been addressed by recognizing a potential focus on both rural and urban transportation with a national target market. Note though that the statement of need is still phrased in the context of rural transportation, which is WTI's area of expertise. Market research done in the business plan should provide further guidance in these areas.

The next step is the production of a business plan. This document outlines and details many of the capabilities potentially available to this program, and lists a number of scenarios in which the program might operate. These scenarios are diverse, spanning the identified focus areas of Education, Research and Application. Further information is provided regarding potential stakeholders, competitors, funding sources, etc.

The business plan will be produced by a subcontractor, Shel Leader, using this document as a basis of information and as the definition of the program concept.

It should be noted that this document, as a compilation of numerous contributor's comments, is not intended or ready for publication. It is an internal document.

STATEMENT OF NEED

In rural and small urban areas, highway transportation presents a broad spectrum of challenges: isolated roads, limited communications coverage, challenging terrain, extreme weather, inadequate public transportation, and conflicts with the environment. Advanced technology has proven beneficial in dealing with these challenges. However, rural and small urban areas are also particularly susceptible to technical problems related to inadequate systems engineering and integration due to a shortage of personnel having experience with advanced technologies and systems engineering processes. Establishing a program will allow us to better address these issues in rural and small urban areas nationwide. The program will help to attract high quality engineering and scientific staff to Montana State University, and will create a strong research, education and support infrastructure of direct benefit to organizations that face these challenges.

MISSION STATEMENT

The mission of the Systems Engineering and Integration of Transportation Technology Program (SEITTP) is to develop, promote and apply interdisciplinary skills and services necessary to implement best management practices and solutions for the integration of advanced transportation technologies within rural and small urban settings.

EXECUTIVE SUMMARY

Development and deployment of advanced transportation technologies is, of necessity, a multidisciplinary process requiring the application of advanced skills in civil engineering, computer science, electrical and computer engineering, industrial engineering, mechanical engineering, human factors engineering, and sciences such as ecology, chemistry, and economics. Currently, the transportation industry has a severe shortage of personnel who have the knowledge and experience to bring these disciplines together into effective teams and solutions, particularly in rural and small urban settings. There is also a lack of knowledge about best management practices for integrating the products of these disciplines.

Development and deployment of advanced transportation technology is a process of seven interdependent steps: (1) identify the need for a technological solution to a problem, (2) research the underlying technical questions about the operational principles of the technology, (3) engineer to convert the underlying principles of the technology into practice, (4) deploy the technology into the transportation infrastructure, (5) operate and maintain the technology, (6) evaluate the technology, and (7) decommission the technology when its useful life is completed. Systems engineering and integration link these steps together as a structured engineering process. This process is often neglected due to lack of resources such as funding, time, manpower, and expertise necessary to bring together an effective, multidisciplinary team.

To address this problem, the Western Transportation Institute at Montana State University-Bozeman proposes to leverage its existing status and expertise to form a Systems Engineering and Integration of Transportation Technology Program (SEITTP). This program will bring together a multidisciplinary team of engineers, scientists and students from a broad range of university departments to address the education, research, and application issues of systems engineering and integration in relation to advanced transportation technology.

WTI is the largest national Research and Special Programs Administration University Transportation Center focused on rural transportation. A cooperative transportation research effort between the California Department of Transportation, Nebraska Department of Roads, Montana Department of Transportation, and Montana State University-Bozeman, WTI has an ongoing $8 million annual budget and a portfolio involving 35 states and six countries. WTI has an expanding emphasis on rural public transit, advanced transportation technologies, winter mobility, transportation infrastructure, and vehicle/wildlife interactions.

WTI, through the SEITTP and in conjunction with the Montana State University College of Engineering, will provide education, research and application support for systems engineering and integration to client organizations by:

- providing workforce development and continuing education opportunities in systems engineering and integration for transportation professionals. It will promote systems engineering and integration training as part of the undergraduate and graduate

engineering curriculum, and will provide students with the opportunity to apply what they've learned in the classroom to "real-world" problems.

- providing multidisciplinary transportation-related research and development opportunities for engineering and science faculty, staff and students, and will use and promote WTI, COE and other MSU labs and facilities for systems integration efforts. It will use technology transfer and the publishing of research results to promote the application of transportation-related research in systems engineering and integration.
- supporting the development of emerging transportation technologies, and assisting to evaluate and implement state-of-the-art technology, evaluating existing conceptual design products under actual use conditions, and developing and providing best management practices for integration of these technologies.

FOCUS AREAS

Education

The program will provide workforce development and continuing education opportunities in systems engineering and integration for transportation professionals. It will promote systems engineering and integration training as part of the undergraduate and graduate engineering curriculum, and will provide students with the opportunity to apply what they've learned in the classroom to "real-world" problems.

Research

The program will provide multidisciplinary transportation-related research and development opportunities for engineering and science faculty, staff and students, and will use and promote WTI, COE and other MSU labs and facilities for systems integration efforts. It will use technology transfer and the publishing of research results to promote the application of transportation-related research in systems engineering and integration.

Application

The program will support the development of emerging transportation technologies, and assisting to evaluate and implement state-of-the-art technology, evaluating existing conceptual design products under actual use conditions, and developing and providing best management practices for integration of these technologies.

POTENTIAL USAGE SCENARIOS

WTI staff and a subcontractor, Shel Leader, suggested a number of potential usage scenarios for the proposed program. These scenarios span the focus groups – education, research and application – and are somewhat open-ended at this point. Several address specific (potential) projects, others suggest possible project sources, and others are more generic in nature. There are also two that specifically address separate potential education programs that would dovetail

nicely with the proposed SEITTP, but would require extensive involvement and management from COE faculty.

There are certainly many other potential usage scenarios for the program.

Gallatin Canyon – Hwy 191

Focus Areas:

All

Stakeholders:

MDT, Gallatin County, EMS Agencies

Problem Description:

Highway 191 is a high use roadway that has a large number of associated incidents/fatalities. It is a prime candidate for study, and would be a valuable "test-bed" for technologies such as wireless and satellite communications, sensors, animal detection systems, dynamic message signs, and cameras at key locations.

This project would dovetail with current WTI research, specifically the TRAIL project, Redding Responder, RADS test-bed, and the Bozeman Pass project.

Services:

The center would participate in developing and evaluating various technologies for use in the canyon. The canyon provides communications challenges that might benefit from Richard Wolff's expertise in the area of Telecommunications. Computer Science, Civil, Electrical, Mechanical, and Industrial Engineering could all provide solutions for powering systems, relaying, displaying, and analyzing data, etc. If cameras were to be used, there would be a need for image processing and compression/analysis.

Funding Mechanism:

Unspecified.

Knowledge Management

Focus Areas:

All

Stakeholders:

Systems Engineering & SEITTP as service provider

WTI, DOTs, or Transit organizations as end users

Problem Description:

For any complicated projects such as transportation projects, the knowledge every expert has is quite different, ranging from the highly quantitative knowledge (e.g., mathematics and physics) to the qualitative knowledge (e.g., social sciences, human factors, and management). The first challenge is to establish a systematic procedure/method to identify, create, and store the knowledge (quantitative and qualitative) from numerous projects that have been completed by WTI/DOT in the past. The next challenge is to manage the developed knowledge system, which the future projects can put to good use.

Services:

This knowledge management system will be able to help determine the efficient mechanism for connecting people by studying the routings, movements, and interactions of knowledge, so that the right people can be assigned to the right tasks for successful project team and engineering management.

Funding Mechanism:

First stage: UTC funding is needed to establish the basic framework, using WTI as a showcase organization.

Second stage: With preliminary results from the WTI case study, NSF funding can be pursued to enrich and improve the knowledge management system.

Third stage: With a system tested for WTI, funding from state DOTs, transportation pooled fund (TPF), the National Cooperative Highway Research Program (NCHRP), or Transit Cooperative Research Program (TCRP) could be pursued to extend its application to other organizations.

Systems Engineering and Integration Database for Transportation

Focus Areas:

All

Stakeholders:

All possible program stakeholders would benefit.

Problem Description:

The SEITTP could facilitate the development and maintenance of a database of system integration procedures and methodologies. Systems Integrators often create unique solutions for every problem encountered. However, individual elements of the solution likely come from previous experience. Documenting, cataloguing, and making solutions available would help to reduce overall costs associated with solving new or similar problems. Information could be categorized by general topics such as: “Weatherproof connectors used for RS232 Communication Link,” “Mounting Brackets for High wind Conditions,” “Embedded Applets for

Control of Detectors," etc. A small fee could be charged to help cover the cost of operating and maintaining the database.

Services:

The database would be made available to students, researchers and practitioners, disseminating lessons learned and best management practices for the purposes of education, research and application. The center would create and manage the database and assist users (help desk) with research services.

Funding Mechanism:

A fee could be charged to help cover the cost of operating and maintaining the database. There could be "pay-as-you-go" fees and subscription services. There could potentially be donations from database software companies or from technical foundations seeking to encourage compilation of information databases.

Customized systems engineering support for projects

Focus Areas:

All

Stakeholders:

SEITTP as service provider

WTI, DOTs, or Transit organizations as end users

Problem Description:

Transportation projects involve various stakeholders and end users, and the products of these projects may interact with legacy systems or other infrastructure. Systems engineering methodologies should be adopted to make sure that the delivered product/service meets the needs of end users and fits well into the existing architecture. For instance, in the planning stage, stakeholders and their roles should be identified, system requirements should be investigated, and integration with legacy systems should be considered.

Traditional systems engineering methodologies were designed for multi-million dollar projects and are not necessarily applicable to small projects often encountered in rural transportation environment. It is a challenge to determine what degree of systems engineering should be adapted to a project to take advantage of its strength without compromising the budget/schedule of the project.

Services:

The Program can provide systems engineering support customized to meet the needs of specific projects by:

- Gathering and analyzing system requirements

- Documenting concepts of operations
- Facilitating risk management
- Facilitating configuration management
- using other systems engineering tools, as applicable

Funding Mechanism:

With a customizable system tested for WTI projects, funding from state DOTs, transportation pooled fund (TPF), the National Cooperative Highway Research Program (NCHRP), or Transit Cooperative Research Program (TCRP) could be pursued to extend its application to other organizations.

Systems engineering training for transportation professionals

Focus Areas:

All

Stakeholders:

SEITTP as service provider

WTI, DOTs, or Transit organizations as end users

Problem Description:

Transportation projects involve various stakeholders and end users, and the products of these projects may interact with legacy systems or other infrastructure. Systems engineering methodologies should be adopted to make sure that the delivered product/service meets the needs of end users and fits well into the existing architecture. For instance, in the planning stage, stakeholders and their roles should be identified, system requirements should be investigated, and integration with legacy systems should be considered.

Services:

The Program can help the user to:

- understand the principles of systems engineering
- understand the manner in which the National ITS Architecture and system standards support the systems engineering process
- understand the principles of systems integration

Funding Mechanism:

Funding from state DOTs and transit organizations could be pursued.

Greater Yellowstone Tour District

Focus Areas:

All

Stakeholders:

Yellowstone and Grand Teton National Parks; Gallatin County, Park County, and other regional counties; START Transit (Jackson); Bozeman, West Yellowstone, Idaho Falls, Cody; Private transportation providers; INEEL; GYT Clean Cities Coalition; Yellowstone Business Partnership; visitors; local commuters; seniors and people with disabilities.

Problem Description:

A diverse group of public and private interests have succeeded in developing a modernized vehicle, the New Yellow Bus, aimed at providing exciting new transportation choices in our national parks and gateway communities in all seasons. The next step in taking advantage of the potential of this bus to provide new economic opportunities to the communities surrounding the parks is to study and plan a network of these vehicles in and around Yellowstone and Grand Teton National Parks.

The vision is to share resources and opportunities through a Greater Yellowstone Tour District that will coordinate across three states and two national parks, a region roughly the size of Connecticut. This tour district will encompass the issues of transportation, energy use, Intelligent Transportation Systems, and winter use of the parks. The New Yellow Bus vehicles will be owned or run by private tour companies, public transportation districts, parks, senior and disabled transportation providers, or other organizations that serve the Greater Yellowstone economy. The tour district will be in place to share these vehicles and services across the different members and to provide information to the travelers in a cohesive manner. Other opportunities for cooperation, coordination, or consolidation will be included as groups of stakeholders identify and agree to them.

A key component of the implementation of this new Tour District is the evaluation and planning of what is available, what is needed, where it is needed, and what will be provided.

Services:

- Regional workshops
- Stakeholder needs assessment
- Logistical design of routes, vehicle distribution, maintenance capabilities, etc.
- Define ITS needs
- Define ITS requirements
- Evaluate effectiveness of ITS solutions
- Develop applications if they are not commercially available

- Evaluate effectiveness of the tour district including changes in travel behavior and economic impact
- Investigate impact and issues from the political science perspective
- Document the process used to develop the tour district and share with other regions with shared characteristics
- Incorporate some of these efforts into senior design courses, masters thesis, and other educational opportunities.

Funding Mechanism:

Congressional designation of funds; non-profit foundations

Alabama Voting Rights Transportation System

Focus Areas:

Research, Application

Stakeholders:

Alabama DOT, Selma Voting Rights Trail (NPS), City of Selma, City of Montgomery, visitors; local commuters; seniors and people with disabilities

Problem Description:

For greater economic return on investment, the New Yellow Bus has been designed to meet the needs of the National Park Service and community transportation. Its use in the Greater Yellowstone region should be replicable in other federal lands applications in rural areas. To test this theory, funding is being requested for implementation along the newly designated Selma Voting Rights trail in Alabama. The region is looking for 3-4 vehicles, transit ITS, and funding to identify coordination opportunities with nearby planned and existing public transit systems.

A key component of the implementation is the evaluation and planning of what is available, what is needed, where it is needed, and what will be provided.

Services:

- Logistical design of routes, vehicle distribution, maintenance capabilities, etc.
- Define ITS needs
- Define ITS requirements
- Evaluate effectiveness of ITS solutions
- Develop applications if they are not commercially available
- Evaluate effectiveness of the tour district including changes in travel behavior and economic impact

- Investigate impact and issues from the political science perspective
- Document the process used to develop the tour district and share with other regions with shared characteristics
- Incorporate some of these efforts into senior design courses, masters thesis, and other educational opportunities.

Funding Mechanism:

Congressional designation of funds; non-profit foundations

Hardware Testing, Evaluation and System Integration Solutions for Manufacturers

Focus Areas:

Research, Application

Stakeholders:

Manufacturers/Distributors/Value-Added-Resellers/System Integrators

- Funding
- Engineering Support

Departments of Transportation (Would be given general information about product type, but not specific name of manufacturer or actual hardware)

- Oversight
- Review of Testing Procedures
- Review of Test Results

Montana State University

- Department support as required for specific products

Project Description:

Manufacturers want products tested to determine suitability for use in traffic and freeway management situations. Often products must function under severe circumstances which include: significant road vibration (such as location on an elevated structure); severe weather conditions; dust and corrosion; minimal power and telecommunication service availability.

They must account for:

- hardware testing to certify compliance with specific standards. For this purpose, standards would be transportation related. Compliance certification would be for specific products and situations.

- integration their equipment into legacy systems.
- integration their equipment into new systems.
- proof of compliance with project specifications.

Services:

SEITTP would provide evaluation and testing services to hardware and software manufacturers. Manufacturers would pay a nominal fee for the testing of products to determine if they meet stated specifications and to receive recommendations for changes. SEITTP would provide test beds to determine and recommend best management practices, and would look at potential systems integration problems. SEITTP could also conduct customer surveys of customers to determine the need for product enhancements.

SEITTP could provide:

- laboratory testing of products.
- controlled "real-world" scenario testing in field conditions and simulated actual use conditions.
- investigation of legacy systems to determine product suitability, with recommended integration procedures.
- investigation of new system requirements to determine best procedures for integration of specific hardware.
- comparison of manufacturer products with project specifications to certify compliance.

Funding Mechanism:

All services described in this scenario would be funded by the party/s making the request. Budgetary estimates would be provided with progress payments when specific elements of the testing are completed.

Hardware and Software Testing, Evaluation and System Integration Solutions for Departments of Transportation

Focus Areas:

Application

Stakeholders:

Departments of Transportation

- Oversight
- Review of Testing Procedures
- Review of Test Results

Montana State University

- Department support as required for specific products

Problem Description:

Departments of Transportation need products tested to determine suitability for use in traffic and freeway management situations. Often products must function under severe circumstances which include: significant road vibration (such as location on an elevated structure); severe weather conditions; dust and corrosion; minimal power and telecommunication service availability.

They must account for

- hardware and software testing to certify compliance with specific standards. For this purpose, standards would be transportation related. Compliance certification would be for specific products and situations.
- integration of new hardware and software into a legacy systems.

Services:

SEITTP could provide:

- product testing.
- controlled "real-world" scenario testing in field conditions and simulated actual use conditions.
- investigations of legacy systems to determine product suitability, with recommended integration procedures.
- investigations of new system requirements to determine best procedures for integration of specific hardware.
- comparison of manufacturer products with project specifications to certify compliance.

Funding Mechanism:

All services described in this scenario would be funded by the entities making the request. Budgetary estimates would be provided with progress payments when specific elements of the testing are completed. Some funding may be provided via "ear mark" in State and Federal programs.

California Narrows Project

Focus Areas:

Research

Stakeholders:

Caltrans

- Develop problem statement

- Provide funding
- Provide real-world test location

Hardware Manufacturers

- Provide hardware and software for testing
- Provide engineering and technical support

Montana State University

- Department support as required for development
- WTI Staff provide traffic and transportation engineering support

Problem Description:

Caltrans needs a system to detect over width vehicles attempting to use section of roadway that cannot support over width vehicles. WTI staff would like to test several systems, each representing a different technology solution.

Services:

SEITTP could provide:

- Gain understanding of individual system requirements for installation, communication and power.
- Determine potential system conflicts when installed for side-by-side comparison.
- Create test procedures to measure individual system performance
- Create test methodology for comparing system results.
- Make recommendations for best installation practices.
- Support WTI staff with deployment of selected system at Caltrans location.
- Support WTI staff with final evaluations.

Funding Mechanism:

- Caltrans provides funds for overall test
- Vendors provide "in-kind" support and hardware/software for testing.

Integrative Graduate Education and Research Traineeship (IGERT)

Focus Areas:

Education

Stakeholders:

Faculty and graduate students at MSU's College of Engineering and other center affiliated academic departments.

Participating faculty would foster collaborative research initiatives that transcend disciplinary boundaries and are centered on transportation systems engineering and integration. PhD level graduate students would actively be recruited to participate in this research. Interdisciplinary curriculum development would provide a cohesive focus for the graduate program (a certificate could be offered, for example, in transportation systems integration. In addition to related research work, certificate requirements could include coursework on systems engineering, ITS, and transportation systems integration. A program of industry or government traineeships would add additional benefit to students and cohesion to the program as well).

Project Description:

The SEITTP aims to improve deficiencies noted in the current transportation workforce with respect to advanced technologies, to increase the transportation research capabilities of MSU by attracting high quality engineering and scientific staff to the university, to solve systems integration issues related to advanced transportation technologies, and to advance the state of the art. An integrated, research-based interdisciplinary graduate training program centered on the integration of cutting edge advanced transportation technologies would promote these objectives. Interdisciplinary research activities, theme-based graduate course offerings, and industry and government traineeships would form the backbone of the program. Recruitment and retention strategies would be developed to ensure that the program graduated a diverse pool of PhD students in science and engineering with expertise relevant to both academic and non-academic careers in the transportation field.

Services:

Research efforts would be pursued under select focus areas to address existing issues with advanced transportation technologies and to advance the state of the practice. Career placement of graduates with integrated research and professional experience and skills would address deficiencies in the current transportation workforce. Industry research needs with respect to advanced transportation technologies could be addressed through sponsored research through the integration center.

Funding Mechanism:

- NSF funding through the Integrative Graduate Education and Research Traineeship (IGERT) program would cover student stipends, recruitment expenses, administrative costs, and some faculty buy-out time for program-related curriculum development and teaching.
- Industry and government sponsorship would cover research costs for select projects.

Engineering Research Center (ERC)

Focus Areas:

Education and Research

Stakeholders:

Faculty and students at MSU's College of Engineering and other center affiliated academic departments.

Participating faculty would foster collaborative research initiatives that transcend disciplinary boundaries and are centered on transportation systems integration. Research initiatives would specifically focus on industrial and government partners' needs in the realm of real-world transportation technologies. Graduate and undergraduate students would actively be recruited to participate in this research. Research initiatives and innovations developed in the ERC would be translated to the classroom at MSU and to university partners' and K-12 classrooms through coordinated outreach efforts.

Project Description:

The SEITTP aims to improve deficiencies noted in the current transportation workforce with respect to advanced technologies, to increase the transportation research capabilities of MSU by attracting high quality engineering and scientific staff to the university, to solve systems integration issues related to advanced transportation technologies, and to advance the state of the art. The establishment of a NSF Engineering Research Center (ERC) would provide funds to adequately staff and equip such a center. In addition, the prestige of an ERC would facilitate faculty and research staff hires, graduate student recruitment, and success rates in obtaining sponsored research contracts from industrial and government partners on a national basis. Increased research opportunities for faculty and graduate students from various engineering departments would expand the interdisciplinary expertise available to the center. Research and education initiatives centered on the integration of cutting edge advanced transportation technologies would promote workforce development in this field while addressing the needs of the ERC's industrial and government partners.

Services:

Research efforts would be pursued under select content areas to address existing issues with advanced transportation technologies and to advance the state of the practice. Career placement of graduates with integrated research and professional experience and skills would address deficiencies in the current transportation workforce. Industry research needs with respect to advanced transportation technologies could be addressed through sponsored research through the ERC.

Funding Mechanism:

- NSF funding through the Engineering Research Center (ERC) program would cover administrative salaries, outreach efforts, experimental equipment and laboratory space.
- Industrial partners would pay membership fees to the Center and would form a technical advisory board to ensure that successful technology transfer strategies were practiced.
- Industrial and government partners would sponsor specific projects based on their research needs.

Other suggested potential scenarios from staff:

- Application of systems engineering process to rural ITS projects
- Paratransit operations and routing studies, using Galavan (Big Sky Transit and Bobcat Transit???) as a testing ground
- Evaluate rural transit ITS applications
- Courses or seminars in systems engineering for rural ITS aimed at affiliated MSU members, MSU students, or continuing education
- Assist local agencies (cities, counties, transit agencies, state non-DOT departments, tribal entities, parks) in developing RFP's, requirements, concepts of operations, evaluations, etc.
- Turning the pavement temperature thermal model into a product that is useful to end users
- Bozeman Pass testbed for weather and winter mobility issues – instrumentation, plows w/ GPS, etc.
- Montana Transportation Management Center staffed by MSU students

Comments from Susan Gallagher, WTI Education Coordinator, Regarding the Connection Between the Program and the IGERT and ERC Programs:

I looked over the ERC RFP. I think it fits very nicely with the SEITTP goals and objectives and should be pursued. One thing to note, this will require significant faculty participation as LEADS on the project (i.e. the PI and Center Director, Deputy Director, and Education Program Director must be tenure-track faculty members according to the NSF requirements).

Thanks for forwarding the emails and materials to me related to the SEITTP concept refinement. Attached are some ideas regarding concept development for the Integration Center. I have included IGERT and the ERC as possible scenarios under potential usage. After giving this considerable thought, I believe it is premature to try to submit a proposal for the IGERT at this time. Instead, I suggest that both the IGERT and ERC need to be one aspect of the concept development and feasibility study that is being undertaken currently. Both require extensive commitments from faculty for graduate student recruitment and mentorship, program management and development, and curriculum development and change. In fact, we will need to identify a core group of faculty to serve as PIs for either or both of these programs should we decide to proceed with proposals for them. We will need to hash out what this means to WTI in terms of playing a key role in the organization and administration of these programs as we will need to give up some measure of control. In addition, both IGERT and ERC programs require the development of (and commitments from) industrial partnerships. Until we have a more specific concept for the center hashed out and have taken a complete inventory of potential partners, stakeholders, faculty participants, facilities and equipment, etc. through the feasibility study, it will not be clear how the IGERT or ERC programs can be integrated into the plan. I would like to suggest that we work together more closely over the coming months so that each step in the concept development process and feasibility study includes a clarification of corresponding educational goals and objectives. In particular, it would be good to be able to add

education-related questions to any materials sent to faculty for feedback and comment. Please let me know if this idea is compatible with your planned course of action regarding the Center.

INTERNAL CAPABILITIES

WTI Staff

There are a number of WTI staff who have been identified for involvement with the potential program. Certainly all WTI staff could play a role in and/or benefit from the program. In addition to research staff, WTI has a capable and diverse support staff providing services such as accounting, technical writing and editing, graphic design and publication. WTI senior management has extensive management and research experience in transportation and transportation research. WTI research staff has expertise and education ranging from Civil Engineering to Computer Science to Wildlife Biology to Human Factors. WTI is currently in the process of adding a researcher to provide support in systems engineering. In addition, WTI has staff experienced in training of undergraduate and graduation students as well as professionals in continuing education and workforce development.

Several staff members provided background information that may be of relevance to the center, some in greater detail than others. Some are listed in name only, and further information can be gathered regarding their capabilities later.

- Steve Albert, WTI Director
- Mike Kelly, WTI Research Director, PhD, Human Factors
- John Taylor, WTI Deputy Director
- Doug Galarus – M.S. Computer Science, M.A.T. Mathematics – extensive experience in software and systems development, IT management, technical writing and training, education, operations research, systems analysis and software/systems engineering.
- Suzanne Lassacher, M.S. Computer Science, Driving Simulator Sys Admin and Programmer, WTI systems administrator
- Xianming Shi – PhD in Chemistry, Master's in Industrial and Management Engineering; trained in Systems Analysis, Decision Support, Operations Research, Quality Insurance; interactions between materials and the environment; has taken training in Applied Systems Engineering for Advanced Transportation Projects. systems engineering, interactions between materials and the environment
- Lisa – transportation systems engineering; coordinate between end users and people unfamiliar with transportation field. before WTI, 5 years experience working with multi-discipline team on developing advanced transportation management systems, developing designs for installing field devices (CCTV, CMS, ramp metering, traffic detectors), traveler information kiosks, applications for both cities and transit systems. Designed user interfaces; upgraded the design of an expert system for assisting operators in incident management. Rural transit applications. 511. RWIS. Understand state of the practice in weather applications. Conversational understanding of databases (Oracle,

mySQL, Access, queries, scipts, database design, data dictionaries, backups, etc.), programming, UI design, etc.

- Susan Gallagher, WTI Education Coordinator
- Jaime Eidswick – MDT, traveler info, 511, message sets, beginning to learn about NTCIP and other systems engineering related stuff.
- Chris Strong – architecture, evaluation, safety
- Pat McGowan – ITS evaluation, some architecture, transportation engineering algorithms
- Research associates, other WTI engineers, researchers and student fellows and interns, coordinator for student recruitment/retention and education initiatives, administrative support (accounting, communications, graphics, computer support).

WTI Facilities and Equipment

WTI has an ever-growing list of facilities and equipment. Some of these items are "owned" by WTI, while others are shared with other organizations such as COE. The following listed items are either current or anticipated items. Greater detail is given for some. Additional detail can be gathered, if necessary.

Student Support:

Graduate student offices (13 spaces), undergraduate computer lab (10 computers), transportation simulation software packages (Tait Computer Lab) [computer and work space support for students working on interdisciplinary transportation research. WTI student space is available on a first-come-first serve basis. Tait computer lab is available to CE students unless classes scheduled there. Not currently available summer to students but could possibly make arrangements with CE if needed].

Driving Simulator:

The Driving Simulator allows testing of driver performance and behavior in the safety of a controlled laboratory environment. Collection of data related to driving hazards and unsafe conditions is dangerous and time consuming if done on actual highways or test tracks. Because of the changing nature of environmental conditions and traffic, it is impossible to maintain the full control of driving scenarios necessary for experimental precision. This can be accomplished safely and easily in a simulation laboratory designed to collect detailed measures of driver performance during high fidelity, realistic driving scenarios.

Exploratory research on new traffic engineering practices and devices often cannot be performed in real world traffic scenarios. A research simulator would allow testing and development of prototype and notional systems before they can be fielded. The laboratory would economically support research in safety, control theory, psychology, driver fatigue, alcohol and OTC drugs effects, and other topics that are difficult to study in low fidelity laboratory simulations or on the real roadways.

The DriveSafety DS500C Vection simulator features five visual channels providing approximately 140-degrees of view plus rear-view mirror. The visual simulation allows the driver to drive through scenarios including roadways, buildings, traffic signs and signals, other vehicles, trees, rain, snow, fog, and even animals in the roadway. Auditory displays provide a realistic sound environment. A driving cab contains the driver seat and all fully functional displays and controls. An automated performance measurement system collects a broad range of data on the driver's control inputs and performance. An operator station allows the researcher to program and control the research scenarios.

The simulator utilizes high-resolution textured graphics (800 x 600 pixels) on each of five visual display channels arranged in a semicircle around the front of a cab that is actually a quarter of a Saturn sedan. The visual displays run efficiently in real-time – maintaining a 60Hz update rate with a 48 msec latency. All roadways and traffic control devices are geometrically correct and modeled to highway design standards. The simulator can replicate up to 256 autonomous ambient vehicles to create traffic for the simulated environment. The autonomous vehicles obey all traffic laws and traffic signs. It is also possible to script specific behaviors for the ambient vehicles to create traffic conflicts.

The simulator is the only one of its kind in the Pacific Northwest. The cost of such a high fidelity driving simulator at MSU would be leveraged into funding for multidisciplinary research grants from Federal and state transportation and research agencies. It would serve as a laboratory supporting faculty, undergraduate, and graduate student research projects from numerous departments across the campus.

Some specific research areas that have been suggested by WTI staff that could yield funding include the following:

- Driver distraction (e.g., with mobile phones) as a major cause of accidents.
- Driver understanding of dynamic messaging systems.
- Aging related deficits in driving performance.
- Winter driving performance and weather warning systems.
- Computer-based systems to assist driving performance.
- Driver behavior and safety in the rural versus urban environment.
- Driver behavior when encountering obstacles such as large animals.

Mobile laboratory infrastructure

Includes data acquisition, weather station, GPS handheld instruments, 4KW A/C Power, 4WD, full mechanics tool inventory, other unique equipment and systems; Resources – ME Instrumentation Lab, inventory of sensors & data acquisition equipment.

Transportation, Research, Applications, and Instrumentation Laboratory (TRAIL):

The Western Transportation Institute's Transportation Research, Applications and Instrumentation Laboratory (TRAIL) will demonstrate and evaluate various data acquisition, control systems, information delivery, and management systems in a small urban and rural environment.

The goal is to establish a travel corridor for 19th Street in Bozeman that promotes a safe and efficient traveling environment for its users. The diverse nature and increasing traffic volumes of 19th Street qualifies it as an appropriate candidate for the initial phase of this project. Traffic volumes on 19th have currently exceeded projected expectations and continue to increase. High traffic volume promotes safety and delay concerns. Given the increased development along the 19th Street corridor, we expect an even greater increase in traffic volume, congestion, and incidents over time. Deployment of traffic, weather, and road condition sensors will allow WTI to obtain real-time and summary data describing travel conditions. The Groundhog sensors will collect data on roadway conditions (pavement wet/dry), the amount of anti-icing agent present on the roadway, and vehicle information consisting of speed, volume, and classification. Data is collected in five minute intervals. These data will be communicated wirelessly to the TRAIL data management center for processing and archiving. Methods of communicating real-time travel conditions to motorists will be explored.

Data collected by the laboratory would be used for the development of incident response plans, signal timing schemes, and special events traffic coordination. Data could be used as a reference point for future expansion and development plans along the roadway. The transportation research, applications and instrumentation laboratory would be a test bed for a variety of new human factors, weather, pavement, animal detection, and traffic technologies.

**More detail/information can be added on actual technology along with pics.

Facility: The Lewistown Cold Region Test-bed

The Cold Region and Rural Transportation Research, Maintenance and Operations Test-bed in Lewistown, Montana would create the opportunity to perform high quality research and testing on surface transportation issues facing rural and cold regions. The test-bed would create an opportunity to "pool" resources from different partners (private, state, country) to answer both basic and applied research questions that withstand rigorous peer review to meet the credibility needs of various stakeholders and audiences. The research conducted in Lewistown would create the opportunity to develop a national and international Maintenance Research Center of Excellence to address surface transportation maintenance issues and even beyond maintenance as well. The Test-bed can be used by the Systems Engineering and SEITTP to test the interaction of different ITS systems and to experiment the integration of various systems. The Lewiston Cold Region Test-bed has been proposed to the Congress and is likely to be funded this year. After construction, it will be available for use in year 2006 or so.

COE Faculty

COE faculty has expressed great interest in the SEITTP. They have participated in several meetings regarding it, and approximately 10 faculty members provided extensive feedback regarding the concept of the program and their potential contributions to it.

Note that some provided greater detail than others regarding their experience and interests. Further detail could be gathered where necessary.

- Robert Marley (COE) – Dean
- Robb Larson (ME) – MSME, BSME, Registered PE, 8 years Aerospace Industry Engineering Design & Project Engineering, 12 years teaching upper division Mechanical

Engineering coursework, 5 years WTI affiliated faculty; Meachanical Engineering Instrumentation courses, Meachanical Engineering Design courses, ME Computer applications, CAD instructor, Project Design supervisor; Composite materials impact testing, reverse engineering of Diesel Locomotive Engine components, Snow Avalanche characteristics & instrumentation, Transportation system sensors & instrumentations, consulting engineer since 1990 – various product design, analysis, manufacturing support, instrumentation, and expert witness tasks; WTI Affiliated Faculty since 1999 – projects include ODOT ITS planning, MDT Weather Decisions Support Tool, WTI Mobile Laboratory design/construction/implementation/management, MDT Video Traffic Detection contract in work; Resources – Mobile laboratory infrastructure including data acquisition, weather station, GPS handheld instruments, 4KW A/C Power, 4WD, full mechanics tool inventory, other unique equipment and systems; Resources – ME Instrumentation Lab, inventory of sensors & data acquisition equipment.

- Ruhul Amin (ME): Expertise is numerical modeling. Also has background in experimental heat transfer. Mentioned College computing facilities that he uses for work.
- Mike Cole (IE): math modeling & optimization (linear, integer, etc.); simulation (discrete event); background in transportation modeling (freight flows, facility location, fleet management, etc)
- Richard Wolf (ECE) – Gilhousen Telecommunications Chair: expertise and experience in wireless and wired communications systems and information technologies, with applications to telematics.
- Michael Oudshoorn (CS) – Head – involvement most likely to be through the supervision of students working on projects. Can see some of the projects being used in senior design projects and individual problems. Equipment – students could use computers in CS labs is work is purely computational. Suspects that they would need access to equipment for which integration is to be performed. CS does not have extra space to devote to such projects though.
- Don Boyd (I&ME) – could participate on a limited basis. Recently published a text which introduces the first major change in systems analysis and modeling since Jay Forrester introduced systems dynamics more than 40 years ago. Once served as a Professor and Director of the Industrial & Management Engineering Graduate Program at MSU – Bozeman, Dr. Boyd instructed in the following areas: Systems Analysis and Dynamic Systems Modeling, Expert Systems, Statistical Applications and Simulation, Operations Research. Dr. Boyd is the author of a recent published book titled "Systems Analysis and Modeling: A Macro-to-Micro Approach with Multidisciplinary Applications" (Academic Press, October 2000). The book presents a fresh, new approach to systems analysis and modeling with a systems science flavor that stimulates systems thinking. After introducing systems modeling principles, the ensuing wide selection of examples aptly illustrate that anything which changes over time can be modeled as a system. Each example begins with a knowledge base that displays relevant information obtained from systems analysis. The diversity of examples clearly establishes a new protocol for synthesizing systems models. As a retired professor at MSU, Dr. Boyd may be able to provide his expertise to the Center on an as-needed basis.

- Shi-Jie (Gary) Chen (I&ME) – proposes development of knowledge management system for transportation . Serving as an Assistant Professor in the Department of Mechanical and Industrial Engineering, Montana State University (Aug. 2001 - present), Dr. Chen's research focuses on the following areas: Concurrent Engineering and Management, Team Management, Computer Simulation, Project Management. Dr. Chen's expertise in knowledge management, group technology, and project management will be a great asset to the Center. As a tenure-track professor at MSU, Dr. Chen may be able to provide his expertise to the Center in the summer time or on other basis.
- Aleksandra Vinogradov (ME) – suggests integration of her Advanced Materials Lab. Can provide details on test equipment.
- Ahmed Al-Kaisy (CE)
- Jim Peterson (ECE) – Head
- Vic Cundy (M&IE)
- Gary Harkin (CS)
- John Paxton (CS)
- Binhai Zhu (CS)
- Ed Adams (CE)
- Steve Perkins (CE)
- Jerry Stephens (CE)
- Denbigh Starkey (CS)
- Ray Babcock (CS)
- Brett Gunnink (CE)
- Bill Jameson (EE – retired)

COE Departments

COE departments who have expressed interest in the proposed program include the following:

- Civil Engineering
- Computer Science
- Mechanical and Industrial Engineering (Mechanical Engineering, Industrial and Management Engineering) – optimization, simulation, scheduling, human factors
- Electrical and Computer Engineering

Most of the Engineering departments including Mechanical Engineering have senior design projects or "capstone" experience classes at the undergraduate level that are in constant need of real-world problems to investigate. Within the past few years, the concept of multidisciplinary projects has been embraced by the COE, and several departments (ME, EE, Chem E) are actively participating in the multi-D projects. These project courses provide an ideal opportunity for supervised engineering progress on various projects such as those that can be envisioned through

the center. It would be wise for WTI personnel to become familiar with curriculum issues, scheduling, project selection guidelines etc. to be able to utilize this source of (almost free) engineering and ingenuity.

COE Labs and other Entities

COE has a variable of formal and informal labs. Labs from other departments or university-affiliated organizations may also be available, and several are listed below.

- Telecommunications Lab (ECE)
- Image Processing (CS)
- Artificial Intelligence (CS)
- Cold Regions Lab (CE)
- The Transportation Lab – under development (CE)
- Materials Testing Lab
- Geotechnical Lab
- Gilhousen Telecommunications Program: facilities to model, simulate, prototype, test and evaluate communications networks and their applications
- College Computing Facilities – used by various faculty for numerical modeling, etc.
- Advanced Materials Lab – Alexandra Vinogradov
- ME Instrumentation Lab, inventory of sensors & data acquisition equipment.
- IE linear/integer optimization software (AMPL, OPL, CPLEX); Math Analysis (Matlab)

MSU (Other Colleges, Departments and Resources)

As with all Universities, a variety of knowledge and expertise is available through numerous departments and programs. Those specifically mentioned by WTI staff members include:

- LRES (Land Resources and Environmental Sciences)
- GIAC (Geographic Information and Analysis Center)
- Political Science Department.

Affiliated Entities (Example: Tech Ranch)

There are a variety of university-affiliated entities that could be potential partners or could offer or use services for the proposed program. One example is "TechRanch." TechRanch is a business incubator that opened in 2001 to help Montana entrepreneurs develop high-technology businesses that can compete in global markets. TechRanch could, for instance, assist in turning technologies developed through the program into businesses.

EXTERNAL CAPABILITIES

There are certainly a virtually limitless number of outside entities who could be partners in or could provide or derive services from the program. These include public and private entities. Several listed by WTI staff include:

- INEEL Test Track – They have roads that employees use where they can move people from one roadway to another.
- GYRITS projects – ongoing research about the effectiveness of this activity and the equipment that was installed.
- Steering Committee members for GYRTWIS or other past project stakeholders, consultants, etc.
- Possible institutional collaborators and available facilities include Japanese researchers and facilities at the Nagaoka Institute of Snow and Ice Studies (NISIS) and the Institute of Low Temperature Science Hokkaido University (ILTS) and those at the Swiss Federal Institute for Snow and Avalanche Research (SLF). These entities have already signed a collaboration agreement with WTI and the MSU Civil Engineering Department to use available resources for snow, avalanche, and severe weather research most effectively. Collaborative student exchanges between these institutions may also be possible.
- Industrial partnerships (several have been mentioned in the past)
- Federal laboratories
- State DOTs

ADDITIONAL (NEEDED) CAPABILITIES/INFRASTRUCTURE

The subcontractor, Shel Leader, listed the following commentary and items in reference to additional capabilities that would be useful to the program:

Each system integration problem could require a different set of capabilities. The center will have to evaluate each request for support, and determine its ability to handle the problem with internal capabilities, and which will have to be acquired. This will have an impact on the pricing of an individual project. In general the SI Center will be available to accomplish the following:

- Evaluate hardware
- Evaluate software
- Solve specific integration problems.

The three items above were defined under usage scenarios, and would generally require the greatest amount of additional resources, not resident at the University.

Some projects will be designed to evaluate equipment, others to evaluate software, and still others will evaluate both. Each request for support will be presented in the form of a project. The center (under the direction of WTI and the COE) will have some set of testing equipment, tools, spare parts, technical library, and qualified personnel available on opening day. There will also be a protocol established for using additional University facilities and personnel. But, there will always be a need for "outside" resources. Some of these resources will include:

1. Access to standards organizations and their library of documents

2. Personnel with specialized skill sets, knowledge and experience
3. Test equipment
4. Assorted spare parts, cables, connectors, etc.

The following sections will define the four items listed above.

- **Access to standards organizations and their library of documents - Description**
  - A primary consideration to providing a solution for integration problems is the adherence to standards. Most standards allow for some variance while still being compliant. Often, manufacturers will publicize the fact that their products meet a specific standard.
  - A large part of the need for systems integration is generated by the requirement to combine several diverse hardware items into a single system. Each manufacturer stipulates that their product meets the required specifications, but the products may not, in fact, work together without some modification, or adaptation. The staff would need to have access to the specification in order to determine what variances are permitted.
  - RS232 connectors are a case in point. The standard was produced and published by the IEEE (Institute of Electrical and Electronic Engineers) and the EIA (Electronic Industries Association). The standards are identical. A problem arises in the fact that RS232 connectors and cables can be provided in any number of physical formats. Field personnel have been required to create special cable and connector arrangements in order to mate one device to another via an RS232 connection. A systems integrator would normally check for inconsistencies before items are sent to the field for installation.
- **Access to standards organizations and their library of documents – Availability & Acquisition**
  - The University probably subscribes to many standards organization libraries. Make certain that the SI Program personnel are able to access the information.
  - Additional research and information resources can be purchased as needed to fulfill project requirements.
- **Personnel with specialized skill sets, knowledge and experience - Description**
  - The SI program will need to seek out personnel with special skill sets that may be called on from time-to-time to support specific project requirements.
  - Such skill sets may include knowledge of various construction techniques, system implementation techniques, specific knowledge of a specific product or product type. The project manager will have to evaluate the need for personnel, and determine if there is “in-house” expertise or a need to outsource for services.
- **Personnel with specialized skill sets, knowledge and experience – Availability & Acquisition**
  - A list of available personnel with necessary knowledge and skill sets must be developed.
  - Open-ended contracts can be developed with funding applied on a project by project basis.
- **Test equipment - Description**
  - The type of test equipment required will depend upon specific SI problems to be solved.

  - All test equipment will need to be properly stored and maintained. Periodic accuracy checks will be required to assure compliance. This will be especially important if the SI Center does testing for specification compliance.
  - Any University personnel using the equipment will need to be trained on its proper use and care.
- **Test equipment - Availability & Acquisition**
  - Standard testing equipment such as volt meters, continuity testers, connector testers, BERT (bit error rate tester) etc should be purchased at start up.
  - Complex test equipment, such as OTDR (optical time domain Reflectometer), multifunction Oscilloscopes, etc, can be rented for a specific project. Based on use trends, the more expensive and complex equipment can be acquired as needed.
  - Specific needs for large quantities of test equipment can also be met through rental.
  - The University could also lease equipment for a brief period (3 years) and then trade in for a newer version.
- **Assorted spare parts, cables, connectors, etc. – Description**
  - This is basically the same as the test equipment scenario.
  - A certain level of spare parts will be needed on opening day. Additional items can be acquired as projects dictate.
  - Careful records must be kept to assure that spare parts are available.
- **Assorted spare parts, cables, connectors, etc. – Availability & Acquisition**
  - Keep a list of suppliers
  - Have open contracts available to minimize purchasing problems.
  - Buy in bulk using the University's leverage with suppliers.

POTENTIAL STAKEHOLDERS

The subcontractor, Shel Leader, identified the following stakeholders for the prospective program.

Stakeholders:

1. Montana State University
   - A general stakeholder providing facilities to house the SI Center
   - Member of the core team providing policy and general council
   - Client using the educational and research capabilities of the SI Center
2. College of Engineering
   - A general stakeholder providing faculty and research staff
   - Member of the core team helping to develop policy and creating core curriculum for the educational function of the SI Center.
   - A client using the center to meet objectives of research requirements for their clients
3. WTI
   - A general stakeholder responsible for day-to-day operation of the center, marketing its capabilities to prospective clients, and providing overall management and staff.

- Member of the core team responsible for overall program development and securing state and federal funding for research grants.

4. State DOTs
   - State DOT members of the governing council for WTI would be considered as general stakeholders.
   - Most State DOTs would be clients providing funding on a "pay-as-you-go" basis for SI/SE work on Traffic and Freeway Management systems. As indicated in the usage scenarios, DOTs would use the center to solve integration problems associated with the deployment of technology based systems. The center could also be used to review RFP specifications, and responses to the same.
5. FHWA
   - A general stakeholder because they would have an interest in the successful operation of such a center.
   - A client because they would most likely be asked to provide funding for the general operation of the center, and also providing contracts to do specific work.
6. Hardware and Software Manufacturers
   - A general stakeholder because they would have an interest in the successful operation of such a center. You may want to have a manufacturer on the board or governing council of the SI Center. A company like Boeing, a big contributor to the University, and a potential client.
   - A client using the services of the SI/SE center. The ITS/Telematics industry has spawned a number of small to medium size businesses that lack resources to fully fund their own product testing and integration services. The center could be used as an "outsourced resource." Large companies such as General Motors could use the center to perform specific research for new products. Software companies such as Computer Associates might use the center to develop database program designed to specifically support the transportation industry.

POTENTIAL COMPETITORS

The subcontractor, Shel Leader, identified two potential competitor categories, educational institutions and commercial enterprise. It should be noted that other entities such as government research centers might also be considered competitors. Other UTCs might be considered competitors as well. They are listed at the end of this section. Other non-UTC competitors to WTI have been researched and documented, but are not included in this document.

From Shel:

There are two categories of competitors:

1. Educational Institutions
2. Commercial Enterprise

Educational Institutions

Most Universities – especially engineering schools – provide basic systems research for clients on a fee for service or grant funded basis. Many of these schools have transportation programs where faculty and students work on projects that help to either further research on a specific

topic, or in fact provide practical solutions to a problem. A by-product of this is a systems integration process for the specific problem. Additional research may provide a list of educational institutions actively engaged in systems integration work under a fully developed program.

A general WWW search – using "Educational Institutions Systems Integration," as a general search term did not provide a list of educational institutions actively involved in systems integration work. However, the search did provide a significant list of commercial companies.

Several examples of educational institutions involved in SI type work:

- Princeton University has a "Program in Transportation" under the direction of Professor Alain L. Kornhauser. The program is listed with the following description: "The Program in Transportation is an interdisciplinary program offered jointly by the School of Engineering and Applied Science (Operations Research and Financial Engineering) and the Woodrow Wilson School of Public and International Affairs. Faculty members and students from other departments also participate. The interdisciplinary nature of transportation problems is emphasized throughout. In addition to work in their own discipline, all students participate in a common core of courses and workshops dealing with the technological, economic, and social aspects of transportation. Methodological research in network analysis, stochastic systems, large-scale optimization and interactive computer graphics focused on intelligent transportation systems is an area of emphasis for engineering majors." http://www.princeton.edu/pr/catalog/gsa/03/377.htm
- The University of New Hampshire has a Research Computing Center with an "Interoperability Laboratory." The University provides the following description: "A part of the University of New Hampshire's Research Computing Center, the InterOperability Laboratory (IOL) has the dual mission to foster interoperability within the data communications industry and to provide students with a detailed education in data communications technologies. These two mission goals have been combined in a unique partnership between academia and industry where the first goal is actually the mechanism for achieving the second goal, while the second goal fulfills the first. By bringing together parties working on a standard technologies the IOL helps to improve the state of interoperability within the industry. By employing students to develop the test suites, tools, scripts, and to perform the testing, the IOL provides them with a detailed, hands-on apprenticeship. For over fifteen years, the IOL has been successfully fulfilling both missions and has expanded to include activities that go beyond its core mission goals, but that increase the opportunities for students and provide necessary technical assistance to the industry." http://www.iol.unh.edu/general/. The University is working on a research project to develop an intelligent police vehicle. The project is known as "Project 54." This could be considered as an exercise in systems integration. More information is available at: http://www.ceps.unh.edu/news/releases/car54800.html

Commercial Enterprise

There are a large number of commercial entities that do systems integration work. 99% of the work is project oriented. Each client requests a solution for a specific problem. The size of companies involved in this business varies from small independent contractors to multi-billion dollar corporations. These commercial enterprises would compete for general systems

integration business. They would not normally be involved in the research and development aspect that would be a part of SEITTPmission.

Examples of companies doing this type of work include:

- ITS/Communications – the contractor preparing this report
- Siemens ITS – a United States Subsidiary of Siemens specializing in work for the Transportation and Traffic Industry.
- IBM
- Boeing

University Transportation Centers and Related Centers

Center_Name:	Western Transportation Insitute
University:	Montana State University
Research_Area	rural transportation
Focus_Areas	wildlife, rural its, public transit, materials, weather/winter mobility
Center_Name:	Unversity Transportation Center
University:	Assumption College
Research_Area	Transportation and environmental studies
Focus_Areas	Transportation and environmental education for the 21st century
Center_Name:	University Transportation Research Center
University:	City College of New York
Research_Area	Regional Transportation
Focus_Areas	Planning and management of regional transportation systems
Center_Name:	National ITS Implementation Research Center
University:	George Mason University
Research_Area	Transportation Systems
Focus_Areas	Deployment of of intelligent transportation systems
Center_Name:	Midwest Transportation Consortium
University:	Iowa State University
Research_Area	Transportation Asset Management
Focus_Areas	Benefits of winter maintenance, roadway alignments
Center_Name:	Appalachian Transportation Institute
University:	Marshall University
Research_Area	Trans. and Economic Development in Mtn. Regions
Focus_Areas	County trans. Studies and inventories, wildlife, impact of mountains
Center_Name:	MIT Center for Transportation and Logistics
University:	Massachusetts Institute of Technology
Research_Area	Strategic Management of Transportation Systems

Focus_Areas alleviate congestion, surface transportation, institutional innovations

Center_Name: National Transportation Center
University: Morgan State University
Research_Area Transportation: A key to Human and Economic Devel.
Focus_Areas urban transportation problems

Center_Name: National Center for Trans. and Industrial Product
University: New Jersey Institute of Technology
Research_Area Productivity Increases Through Trans. Improvements
Focus_Areas public transit, logistics, provisions of transportation functions

Center_Name: Urban Transit Institute
University: North Carolina A&T State University
Research_Area Urban Transit Performance in Small and Rural Areas
Focus_Areas crash risk reduction, crisis management, traffic control

Center_Name: Center for Transportation and the Environment`
University: North Carolina State University
Research_Area Transportation and the Environment
Focus_Areas wildlife ecology, public transit

Center_Name: Mountain-Plains Consortium
University: North Dakota State University
Research_Area Rural and Intermodal Transportation
Focus_Areas rural transit, environmental impacts, recreational travel, low volume roads

Center_Name: Infrastucture Technology Institute
University: Northwestern University
Research_Area Infrastructure Technology
Focus_Areas remote monitoring technology, structural stability, bridges and dams

Center_Name: MAUTC
University: Pennsylvania State University
Research_Area Advanced Technologies in Trans. Operations & Manag
Focus_Areas bus transit, accident/risk management, pavement maintenance

Center_Name: Institute for Safe, Quiet and Durable Highways
University: Purdue University
Research_Area Safe, Quiet, and Durable Highways
Focus_Areas highway based transit systems, pavement and material design, traffic

Center_Name: Center for Advanced Infrastructure and Transport.
University: Rutgers University
Research_Area Advanced Trans. Infrastructure
Focus_Areas pavement materials, infrastructure, its

Center_Name: Mineta Transportation Institute
University: San Jose State University
Research_Area Policy Guidance of Trans. Management
Focus_Areas transportation and land use, analysis of pre- and post-construction

Center_Name: James E. Clyburn UTC
University: South Carolina State University
Research_Area Professional Capacity Building in Transportation
Focus_Areas public transit, accident prevention, its, designing fuel cells

Center_Name: Southwest Region UTC
University: Texas A&M University
Research_Area Transportation Solutions
Focus_Areas transit, highway, multimodal, economic growth and trade, mobility

Center_Name: UTC for Alabama
University: University of Alabama
Research_Area Management and Safety of Trans. Systems
Focus_Areas rural transit, safety computer programs, crash studies, bridges, work zones

Center_Name: Mack-Blackwell Transportation Center
University: University of Arkansas
Research_Area Rural Transportation
Focus_Areas physical infrastructure, trans. Education, construction, design, materials

Center_Name: Unversity of California Trans. Center
University: University of California-Berkeley
Research_Area Transportation Systems Analysis and Policy
Focus_Areas urban planning, engineering economics, transportation systems

Center_Name: Center for Advanced Transportation Systems Simulat
University: University of Central Florida
Research_Area Advanced Transportation Systems Simulation
Focus_Areas planning, traffic operation, environmental analysis

Center_Name: NCIT
University: University of Denver and Mississippi State U.
Research_Area Intermodal Transportation
Focus_Areas intermodal traffic, traffic systems, intercity travel

Center_Name: National Institute for Advanced Trans. Tech
University: University of Idaho
Research_Area Advanced Transportation Technology
Focus_Areas Alternative fuels and engines, transportation software, lightweight vehicles

Center_Name: Transportation Research Institute

University: University of Michigan
Research_Area Commericial Highway Trans.
Focus_Areas statistical analysis, safety and efficiency of motor cars

Center_Name: Center for Transportation Studies
University: University of Minnesota
Research_Area Human-Centered Trans. Technology
Focus_Areas rural safety, ramp metering, cold weather operations, GPS technologies

Center_Name: Unversity Tranportation Center
University: University of Missouri, Rolla
Research_Area Advanced Materials and Non-destructive testing Tec
Focus_Areas shear-wave velocities, strut failure investigation, bridge rehab.

Center_Name: Mid-America Transportation Center
University: University of Nebraska, Lincoln
Research_Area Design and Operations of Trans. Facilities
Focus_Areas truck parking, rural highways, intersections, MwSWZDI

Center_Name: URI Transportation Center
University: University of Rhode Island
Research_Area Surface Intermodal Trans. Systems
Focus_Areas surface transportation, intermodal systems, environmental prtotection

Center_Name: National Center for Metrpolitan Trans. Research
University: Unversity of Southern Cal. And Cal. SU. Long beach
Research_Area Metropolitan Transportation
Focus_Areas highway capacity, freight routing, public transit, traffic simulation

Center_Name: Center for Urban Transportation Research
University: University of South Florida
Research_Area Transit and Alternative Forms of Urban Trans.
Focus_Areas transit buses, prototype transit materials, repair times of public transit

Center_Name: Center for Tranportation Research
University: University of Tennessee
Research_Area Transportation Safety
Focus_Areas crash predictions models, trans. And emergency services

Center_Name: Transportation Northwest Regional Center-TransNow
University: University of Washington
Research_Area Transportation Operations and Planning
Focus_Areas transportation operations and planning, infrastructure systems

Center_Name: Midwest Regional Unversity Transportation Center

University: University of Wisconsin-Madison
Research_Area Optimization of Trans. Investment and Operations
Focus_Areas systhesis of data, freight corridor study, systems management

Center_Name: CUNY Insititute for Transportation Systems
University: City University of New York
Research_Area Transportation Engineering
Focus_Areas planning, systems management, physical design

Center_Name: School of Civil and Environmental Engineering
University: Cornell Unveresity
Research_Area Civil Infrastructure, Environment
Focus_Areas Systems and management, design and contruction

Center_Name: Georgia Transportation Institute
University: Georgia Institute of Technology
Research_Area Transportation Research and Education
Focus_Areas environmental issues, transportation infrastucture, traffic operations

Center_Name: Civil Engineering
University: Kansas State University
Research_Area Civil Engineering
Focus_Areas environmental, hydraulics, geotechnology, pavement research

Center_Name: Oklahoma Transportation Center
University: Oklahoma State Unversity
Research_Area Transportation and Telecommunications solutions
Focus_Areas advanced materials and pavements, ITS, public trans., energy and

Center_Name: Transportation Research Institute
University: Oregon State Unversity
Research_Area Infrastructure and Transportation
Focus_Areas intel life cycle, nighttime flaggers, cold weather roads, wave and currents

Center_Name: Transportation Research Institute
University: Polytechnic Unversity
Research_Area Transportation Research
Focus_Areas travel demand management, pavement management, construction materials

Center_Name: Department of Civil Engineering
University: Rensselaer Polytechnic Institute
Research_Area computational mechanics
Focus_Areas predictions of earthquakes, electrified roadways, snowloads on stuctures

Center_Name: Department of Civil and Environmental Engineering
University: Tennessee Technological Unversity

Research_Area Transportation Studies
Focus_Areas enviroment, mechanics, structures, transportation, water resources

Center_Name: Institute of Transportation Studies
University: University of California, Davis
Research_Area impacts of tranportation
Focus_Areas travel behavior, environmental vehicle technology, environmental impacts

Center_Name: Institute of Transportation Studies
University: University of California, Irvine
Research_Area solutions to contemporary trans. Problems
Focus_Areas activity systems analysis, ITS, freight and logistics

Center_Name: Institute of Transportation Studies
University: University of California, Los Angeles
Research_Area Transportation Research
Focus_Areas informal travel mode, transit dependence, urban parkways

Center_Name: Transportation Research Center
University: University of Florida
Research_Area Transportation Research
Focus_Areas traffic modeling, intersection design, highway service

Center_Name: Urban Transportation Center
University: University of Illinois at Chicago
Research_Area Urban transportation
Focus_Areas ground level ozone, freight corridors, environmental justice

Center_Name: Kentucky Transportation Center
University: University of Kentucky
Research_Area kentucky transportation
Focus_Areas pavement resurfacing, traffic crashes, effects of warning signs

Center_Name: Department of Civil and Environmental Engineering
University: University of Louisville
Research_Area Infrastucture Research
Focus_Areas rapid void detection, earthquake hazard, elastomer degradation

Center_Name: University of Massachusetts Transportation Center
University: University of Massachusetts
Research_Area Transportation Research
Focus_Areas traffic safety, bay state roads, regional traveler info

Center_Name: Department of Civil Engineering
University: University of Memphis
Research_Area civil engineering

Focus_Areas	bridge and highway design, water water treatment
Center_Name:	Department of Civil and Environmental Engineering
University:	University of Missouri, Columbia
Research_Area	transportation engineering
Focus_Areas	river ports, management systems, railroad crossings, ITS
Center_Name:	Center for Transportation Studies
University:	University of Missouri, St. Louis
Research_Area	transportation studies
Focus_Areas	taxicab curb design, airport ground transportation, technology transfer
Center_Name:	Transportation Research Center
University:	University of Nevada, las Vegas
Research_Area	transportation research, outreach activities
Focus_Areas	pedestrian safety, internet mapping, high crash locations
Center_Name:	Department of City and Regional Planning
University:	Univesity of North Carolina, Chapel Hill
Research_Area	regional planning
Focus_Areas	urban studies, water resources, natural resources, environmental planning
Center_Name:	Department of Electrical and Systems Engineering
University:	University of Pennsylvania
Research_Area	Modeling and design of complex systems
Focus_Areas	sensing and imaging, signal processing, urban transportation, networking
Center_Name:	Center for Transportation Research
University:	University of Texas at Austin
Research_Area	transportation Research
Focus_Areas	asphalt technology, contruction mobility, emissions testing, traffic safety
Center_Name:	Center for Transportation Studies
University:	University or Virginia
Research_Area	Transportation Research
Focus_Areas	ITS, truck flow, accident reduction, information technology, rail transit
Center_Name:	Vanderbuilt Eng. Center for Trans. Operations
University:	Vanderbuilt University
Research_Area	Trans. Research, education and Outreach
Focus_Areas	fleet management and tracking, spatial databases, highway traffic volumes
Center_Name:	Virginia Tech Transportation Institute
University:	Virginia Polytechnic Institute and State U.
Research_Area	Transportation Technologies
Focus_Areas	pavement research, ITS, Smart Road

Center_Name: Department of Civil and Environmental Engineering
University: Wayne State University
Research_Area Applied Transportation Research
Focus_Areas handicap access on buses, crash data processing, computer modeling

Center_Name: Harley O. Staggers National Trans. Center
University: West Virginia University
Research_Area Transportation Research
Focus_Areas pavement modeling and design, transportation planning, aviations

Center_Name:
University: University Of Southern Mississippi
Research_Area
Focus_Areas

Center_Name:
University: Texas Southern Mississippi
Research_Area
Focus_Areas

POTENTIAL FUNDING SOURCES

The subcontractor, Shel Leader, provided the following ideas regarding funding:

Funding sources can be divided into the following categories:

- Government
  - Appropriation
  - Projects
  - Subscriptions
- Alumni
  - Faculty Chair
  - Scholarships
  - Specific Research Grants
  - Matching Funds
- Private Industry (Corporate)
  - Grants
  - Projects
  - Subscriptions

The listed categories can be further defined as startup, short and long term:

- Startup
  - Government can, based on the submitted business plan provide a 3 to 5 year "get-started" appropriation. This would be equal to a decreasing percentage of the required operating budget designed to move the program toward self sufficiency. Example: The program requires an annual budget of $3 million per year to

provide for the total cost of operations, plus $500 thousand for tools, computers, books, etc for startup. FHWA, could provide a sliding scale appropriation of 70% year one; 60% year two; 40% year three; 20% year four; 10% year five.
    - Alumni could contribute to the "tools" budget
    - Corporate donations could also be used to supplement the first year budget.
- Short Term
    - The state governments (on the WTI governing council could provide additional appropriations to help make up short falls in year one and two, with a larger percentage contributed in years three through five.
    - Alumni – continued contributions, plus scholarships and Faculty Chair to support the educational aims of the program.
    - Corporate contributions could be made in the form of subscriptions to news letters, database access, and random calls for information and support. Possible "seat" on an executive council, etc.
    - Corporate funding via actual project work.
- Long Term
    - FHWA and state and local governments will contract for project work.
    - Corporations will contract for project work
    - All categories of customers will subscribe to database access, newsletters via e-mail, and special web site access.
    - Sales of technical books and publications via the University bookstore, and Amazon
    - Continued support from Alumni contribution funds.
    - Sales of specialized software trouble shooting tools

Conclusions:

There are a number of potential sources of income; however, we must recognize that the primary revenue stream should come from project work. That is, if the primary objective of the SI program is to solve system integration problems, that is where most of the revenue should come from.

I am assuming that Alumni contributions and University general funds would be used to support the educational aspects. "Profits" from SI Program activities would be used to support growth and marketing as well as educational programs.

11. APPENDIX B—SYSTEMS ENGINEERING RESEARCH CORE AREAS/THEMES

Systems Engineering Research Core Areas/Themes

1. **Develop usable information technology and communication systems to meet end user needs.** (Develop/Integrate)

   - Create open, standards-based systems that integrate commercial off-the-shelf (COTS) components to meet the needs of end users.
   - Develop collection, aggregation, and dissemination systems to maximize the utilization and application of data.
   - Use technology to identify and overcome challenges imposed by geography, population, budget, infrastructure, policy, workforce and other constraining factors.
   - Apply technology to optimize links between field elements, mobile units, management centers, other agencies, and the public.

2. **Demonstrate systems engineering processes that leverage best practices to maximize limited resources.** (Demonstrate)

   - Identify, develop and apply process models and best practices.
   - Present internally and externally developed systems as case studies.
   - Coordinate and align efforts with technical organizations, standards bodies and other related bodies of knowledge.
   - Maximize the use of forums such as WWW, education/courses, publications, conferences for the demonstration of systems engineering-related efforts.
   - Investigate and demonstrate new media technologies such as blogs and pod-casts for the demonstration of systems engineering-related efforts.
   - Facilitate cooperative, multidisciplinary, multi-agency efforts in systems related efforts to maximize limited resources.

3. **Analyze and evaluate systems and alternatives to recognize capabilities and limitations and to maximize utility.** (Analyze/Evaluate)

   - Assess user/agency needs and requirements.
   - Evaluate systems and products for viability, utility and ease of use in light of constraints.
   - Present unbiased results with an emphasis in applicability.
   - Identify and evaluate applications of cutting and bleeding edge technologies in light of well-established technologies.
   - Establish and demonstrate evaluation criteria and methodologies.
   - Evaluate and apply technology and techniques for GIS, statistical, and operations research related analysis.

4. **Raise awareness of systems engineering via work force development and education at all levels.** (Train/Educate)

   - Determine technology-related needs of DOTS and other agencies for workforce development and continuing education.
   - Work with higher education to develop multidisciplinary curriculum, programs, classes, etc. to address systems engineering needs.
   - Develop, facilitate and conduct systems-related workshops and training courses.
   - Identify and utilize training materials, programs, classes and curriculum to address systems needs.

- Work with professional organizations and student branches such as IEEE, ACM, ITE, ITSA, INCOSE, and others.

12.APPENDIX C—TASKS 4 AND 5, COMPLETED BY MITCHELL K. HOBISH, INDEPENDENT CONSULTANT

WTI Center of Excellence Feasibility Study Phase 2 (Tasks 4, 5)

Prepared for

Doug Galarus
Program Manager

and

Leann Koon
Project Assistant

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Western Transportation Institute
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By

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F I N A L
April 29, 2008

1. General Introduction

As noted elsewhere in the report of which the results reported herein are a part, the Systems Engineering, Development, and Integration Group (SEDIG; the "Group") grew out of the original concept for the WTI Systems Engineering and Integration of Transportation Technology Program (SEITTP), but without specific application or implementation of many of the specifics brought forth in the original concept. True strategic planning processes, metrics for which WTI exponents were directly responsible to a sponsoring agency, were proposed in the application for WTI to become a University Transportation Center (UTC). While such planning and proposal activities were underway, the Group began to form: Staff were hired, projects were sought (and won), and a firm core group of sponsors and stakeholders coalesced around several core systems engineering principles, as practiced in a non-codified manner as the Group proceeded along its growth and development trajectory.

To assess how well the Group has done vis-à-vis the original SEITTP vision, an independent consultant (Sciential Consulting, LLC) was engaged to acquire anecdotal data concerning the Group's activities over the past four years, to assess the degree to which those activities embody the original SEITTP precepts, and to advise as to potential future directions for the Group to take.

The following document is the result of the consultant's activities in support of Tasks 4 and 5 of an internal proposal entitled, "SEITTP Feasibility Study Phase 2". Given the integrated nature of the eight tasks defined in that proposal, there is a certain amount of overlap in issues raised here with those addressed by other tasks in the proposed effort. Such overlap has been kept to a minimum where issues were not the primary focus of a given task. Conversely, where such foci were the primary point of Task 4 or 5, emphasis on cognate issues in other task outcomes should be kept to a minimum.

For both tasks, a specific introduction is presented, along with the methodology by which the consultant undertook to perform on those tasks, and a summary of results. Where possible and appropriate, specific recommendations have been made to help the Group in its future planning.

Mitchell K. Hobish, Ph.D.
Owner
Sciential Consulting, LLC
Manhattan, MT
March-April 2008

2 Task 4: View from the Inside

2.1 Introduction to Task 4: Task Description from the Statement of Work

"WTI personnel and College of Engineering (CoE) faculty who took part in the concept development phase and/or have or are currently working with or as a part of the WTI Systems Engineering program area will be asked to provide a brief perspective on their experiences with this project, including recent efforts and opinions about the future of the program area."

2.2 Methodology

A list of WTI and COE representatives was developed by the program manager in consultation with the Project Assistant. Interviews with the chosen representatives were arranged, and completed over a several-day period. The consultant developed a set of draft questions designed to elicit responses appropriate to address the points necessary to successfully complete the above task description. These draft questions were iterated with the project manager and the project assistant until all were satisfied as to the efficacy of the questions.

The project assistant made arrangements with the chosen organizational representatives for one-hour interviews; there was a two-hour interview with the program manager.

The consultant met with the organizational representatives at their respective offices (except for one instance, where a telephone conversation had to suffice). The consultant recorded the interviews, and subsequently augmented his real-time notes with more-detailed expansion thereof, based on his listening to the recorded interviews. Audio files comprising the raw interviews and the consultant's annotated notes in Microsoft Word format are provided on a separate CD-ROM as Appendices B and C, respectively.

As a result of the interviews and subsequent analysis of the responses, which included integrating responses to similar questions and other issues that arose during the interviews, the consultant developed summary narrative descriptions to address (as noted in the above task description), "…a brief perspective on…experiences with this project, including recent efforts and opinions about the future of the program area."

2.2.1 Interviewees

The following individuals (and their organizational affiliations) were chosen for interviews. The list is presented in the order in which they were interviewed. The sequence—except for Doug Galarus, the program manager—reflects only their availability to be interviewed. Interviewing Galarus first (for a two-hour period) was

deemed necessary to provide the consultant with sufficient background and context to conduct the remaining interviews.

Interviewee	Affiliation	Involvement with Group	Date of Interview
Doug Galarus	WTI, SEDI Group	Program Manager, SEDI Group	March 6, 2008
Suzy Lassacher	WTI, SEDI Group	Research Assistant II; SEITTP planning participant	March 6, 2008
Steve Albert	WTI	WTI Executive Director; SEITTP planning participant	March 6, 2008
Jerry Stephens	WTI; Professor, MSU CoE, Department of Civil Engineering	WTI Research Director	March 6, 2008
Richard Wolff	Professor, MSU CoE, Department of Electrical and Computer Engineering; Gilhousen Telecommunications Chair	SEITTP planning participant; project partner/collaborator	March 13, 2008
Chris Strong	WTI, Safety & Operations Group	Program Manager, Safety & Operations Group; project partner/collaborator	March 13, 2008
Ahmed Al-Kaisy	Assistant Professor, MSU CoE, Department of Civil Engineering	Project partner/collaborator	March 18, 2008 (phone)

The remainder of the documentation for Task 4 consists of an analysis of the perception of the Group generally; more-detailed summaries of the Group's extant strengths, weaknesses, opportunities, and threats; and a description of how well the Group is meeting its stated mission foci. This material ends with an analysis of how the Group as currently constituted and implemented compares with the original concept for the SEITTP.

2.3 Perspectives on the SEDI Group's Activities

2.3.1 General Perceptions

Universally, across all interviewees' responses, was the sense that the Group is performing in an eminently professional fashion, is being clearly responsive to sponsors'

requirements, and is adhering to best practices as regards to management activities and technology choices.

There is some disconnect, however, between the way the Group members view systems engineering and integration (SE/I) and how SE/I is perceived by those outside the Group. In keeping with transportation community norms, the Group has an information technology (IT) and communications focus, whereas those outside the Group see SE/I applicability beyond this centrism. The latter group sees great utility in the Group moving outside its clear evidence of expertise in the IT area.

2.3.2 Extant Strengths

Primary amongst the strengths listed by the interviewees is the presence, influence, and activities of the program manager. Without exception, every interviewee (except the program manager himself, for whom it would have been inappropriate) noted that the program manager was the core of the Group. One interviewee referred to him as "…an engineer's engineer". Part of what makes this assessment noteworthy is that the program manager not only has responsibility for setting the tone for the group, but makes that responsibility real, with a strong commitment to delivering a product according to the sponsor's needs. He impresses this requirement on his staff, and motivates them to deliver.

Implicit in the primary strength described above is that the staff of the Group are well-trained, self-motivated, highly disciplined, flexible, hard working, and, ultimately, perceived of as being highly professional. It must be noted with emphasis that the Group members work exceedingly well as a team and with other WTI staff, partners, and, where appropriate, sponsors. This "team spirit" is often used to best advantage to ensure that developed solutions incorporate the best of what each team member has to offer, as the skill mix is complementary. Team members feel very comfortable calling on each other to augment their individual knowledge bases in generating optimum solutions to sponsors' problems.

As regards the specific discipline areas of SE/I, comments were—again—uniformly favorable, acknowledging the clear IT expertise of the group and their ability to leverage SE/I techniques to respond to sponsors' requirements. That this is routinely done under conditions of limited resources was similarly noteworthy, and that the Group shows a ready willingness to expand their knowledge base as needed to generate the required deliverable. From the standpoint of integration—the emphasis of the original SEITTP concept—familiarity with commercial off-the-shelf (COTS) technologies, their benefits and their limitations, and the ability to develop new solutions where needed and to pull it all together into clearly responsive deliverables goes a long way toward satisfying sponsors' requirements. That the sponsors are clearly satisfied with what the Group presents is testimony to the Group's ability to apply systems engineering appropriately. Similar comments apply to their extensive knowledge base as regards rural communications vagaries and ways to productively deal with them.

The bottom line, as stated by one of the interviewees, is that the Group is comprised of a "…top-notch program manager and staff".

2.3.2 Extant Weaknesses

There were two key weaknesses routinely noted.

As is often the case where there is a key person who forms the core of an organization, that strength is also a weakness, as that person has at least the potential to be a single point of failure for the organization. Such is the case with the program manager who—it was frequently noted—is the linchpin of the Group, and without whom the group would likely "implode", according to one interviewee. For what it's worth, one interviewee opined that this situation is common across many of the functional groups at WTI. That the program manager must handle so much of the Group's technical review, written communications, human resource activities, meeting with sponsors, etc. means that things tend to get shorter shrift than is their due. Many comments were made that what the Group needed was "…a second program manager".

This weakness could be overcome were it not for the second key weakness of the Group, that being the relative professional immaturity of the staff. This is not to denigrate the technical expertise manifested by the group's members: Their technical skill is significant, and the knowledge base grows in breadth and depth with each project. But—except for a few, more-senior members—on the whole, the staff members are still at relatively early stages of their careers. This is particularly problematical when it comes to management expertise and experience, in that several interviewees stated that the Group's staff are not senior enough to be able to communicate well, either as to technical reports, or to generate their own proposals, upon which they could/would then function as principal investigator. Part of this weakness comes from the Group's strength in delivering technologies, in that the Group and its leader would prefer to deal in technology rather than words, and are clearly successful at generating the former, although the latter is increasingly key to overall success. If the staff had more expertise in such communications skills, the program manager could delegate some of this work to them, and thereby reduce the crushing load that he carries.

Part of the genesis of this lack of experience seems to derive from the limited budgets with which the program manager must work, the result of which is that he cannot hire more senior staff. As noted above, however, the Group functions exceedingly well, particularly given the lack of financial and human resources.

Another result—albeit rare—of limited financial resources is that projects can get jammed. Usually this is not because of an inappropriate level of effort estimate (with consequent budget impact) by the Group's members, but because projects naturally tend to evolve over time, with some concomitant change in scope. One interviewee noted that the sponsors are usually good about adhering to the originally agreed-upon

scope, but scope creep is often unavoidable as a project matures. What creep there may be usually arises as a result of a changing understanding of the basic problem being addressed, rather than a desire to add "bells and whistles". This evolution usually entails additional work, work that had not been allowed for in original planning. With an inability to take on additional staff, these changes can cause work jams.

As regards financial resources, several interviewees noted that having the Group 100% dependent on soft money was clearly a weakness.

2.3.3 Extant Opportunities

Overall, based on the interviewees' responses, there was some difficulty in clearly defining where opportunities might lie, owing to an ongoing disconnect between opinions voiced by some interviewees who felt that SE/I was clearly a *supportive* activity, and those who felt just as strongly that it was a discipline area unto itself. Further, there was a lack of congruence as to the future direction for the Group: Should the Group continue its current focus on information technologies and communications as applied to transportation problems? Or, should it widen its focus to accommodate SE/I as a discipline unto itself, worthy of its own research and development and subsequent application to areas that include IT, but extend beyond it to transportation problems generally, and even to areas outside of the transportation realm? [See Task 5 documentation for more on these points.]

That having been said, several common themes did arise. Predictably, these all had to do with leveraging existing knowledge to support a wider range of constituencies. These cover transportation problems at local, municipal, county, state, regional, national, and international levels, via inroads through both the public and private sectors. Further, several interviewees commented on the lack of hoped-for integration with many of the departments in the MSU COE that were originally approached when discussions of an integrated group were first raised, and the opportunities that would likely arise from better communication between the Group and the rest of WTI, and between the Group and those departments. The problem arises mainly from a lack of overlap between the IT-centric focus of the Group and the discipline areas that are the focus of some of those departments, e.g., Civil Engineering.

One interviewee felt that the greatest opportunities not currently being capitalized upon come from openings within the private sector. One approach to addressing this perceived weakness would be to align the Group with industries doing research and development to help support and maintain state-of-the-art research facilities based on established goals over long periods, as distinct from, for example, state-level departments of transportation, the representatives of which tend to come and go, and whose organizational imperatives can, as a result, change frequently.

A key focus area that could combine the best parts of private and public sector interests could be in developing a national communications test bed that would allow exploration

of new technologies with a clearly rural focus, in clear distinction from much of the major work currently underway elsewhere that deals with an urban focus. Not only would this allow WTI and the Group to become better established nationally, but it could lead to programmatic funding, thereby mitigating the problems associated with soft money.

2.3.4 Extant Threats

The perceived threats as voiced by the interviewees fell into two major categories: Competition from other organizations similar in concept and scope to WTI generally and the Group specifically; and the remote geographic location of WTI and the Group, who are situated well outside the mainstream of discourse. One interviewee opined that—in his experience—transportation department managers from larger states would not be inclined to even consider a "small organization in some cow town in Montana" as being qualified to address their needs, preferring to enlist the services of larger, more well-known organizations.

As regards the competition, several interviewees noted that many universities have transportation-related organizations, and that many of those have systems foci, with integration a common thread. Further, private sector organizations, including large companies such as SAIC, Booz Allen Hamilton, and Motorola, are well-equipped to deal with many of the problems that comprise WTI and the Group's focus, although they are not commonly thought of as having an excellent rural knowledge base. However, as an example, this has not stopped a company like SAIC from successfully competing for a Glacier National Park project addressing problems with the Going to the Sun Road. Further, the cost burden that comes from WTI (and the Group's) affiliation with Montana State University could be a discriminator for a sponsor focusing on budgetary matters, although the big-company organizations would likely have similar problems.

As regards the remote location of WTI and the Group, several interviewees suggested that better marketing of the organization(s) would be in order, and that—in some instances, most notably, to keep the Group visible to the California Department of Transportation (CALTRANS)—it may be necessary to open satellite offices to maintain an ongoing presence, thereby to attract more work. In support of this approach to expanding the possibilities for additional work, one interviewee commented that a formal branding effort may need to be instituted, the better to more clearly identify the Group to a wider range of potential customers, the better to keep work coming in.

2.4.3 Concluding Remarks, Task 4

It is clear that the Group is working very well within the well-defined area of applying systems engineering processes to clearly define sponsors' requirements and to integrate applicable technologies to solve IT- and communications-centric problems in a transportation-focused environment. From the perspective of the Group, the leadership is sterling.

That being said, the program manager's own activities may suffer from the sheer mass of work that falls upon him owing to problems attracting more senior staff who could help him with many of the program management and administrative aspects of his position. This shared responsibility would allow the program manager more time to focus on issues that are currently problematic, and would provide potential for additional work—work that would be solicited and subsequently managed by these senior staff members. This may also be the case with WTI generally. The workload for the staff—while cyclical—appears to be manageable, subject to the occasional confluence of deliverable dates.

Student involvement is salubrious for both the staff and the students, only sometimes being affected by the disconnects between academic requirements and those of the applied world in which the Group usually dwells.

Some of the problems that come to the fore take on increased importance when WTI's role as a UTC is included, as part of that mandate is that WTI (and, by extension, the Group) is expected to develop solutions with potential for application nationally, not just regionally. There appears to be little effort to expand the solutions beyond the parochial application required by a given sponsor into this wider arena.

Another area of difficulty comes from the existence of a large number of potentially competing organizations. Most of these are university-based, as is WTI and the Group, but there are also many private sector organizations who could easily compete for work, were such work made competitive to the open market. It appears that while the Group continues to enjoy the approval of its sponsors, reliance on those sponsors is masking other opportunities, and could cause a system failure should champions within those organizations move on or just change their minds.

3 Task 5 - The View from the Outside: Original Concept, What Is, and What Could Be

3.1 Introduction to Task 5: Task Description from the Statement of Work

"The contractor, an expert unaffiliated with WTI and transportation agencies, will review and evaluate the progression of this project from the original vision and mission for a Center of Excellence for Systems Engineering and Integration to its current implementation as a program area within WTI. Recommendations will be made and will include how WTI should proceed with related efforts in the future."

3.1.1 Preliminary Remarks

From a practical perspective, there is always a gap between theory and practice. Such is the case with respect to the original SEITTP concept, as promulgated in the original draft, for-internal-use-only SEITTP planning document, generated by outside consultant Shel Leader and WTI staff, including Suzy Lassacher, Doug Galarus, and Steve Albert, prior to the formation of the Systems Engineering, Development, and Integration Group, and the nature of the Group as currently constituted.

The material that follows opens with a short assessment by the interviewees of how well the Group is doing with respect to their overall goal and intermediate objectives as stated on the Group's Web site (http://www.wti.montana.edu/Systems/Default.aspx, among other documents), and as derived from the original SEITTP concept.

3.2 Methodology

The overall goal of the Group, as stated in internal documentation and at the above-referenced Web site, is "Researching and applying best practices to analyze, engineer, develop and integrate hardware, software and communication systems as applied to transportation." The intermediate objectives, successful attainment of which is necessary to achieve that goal, are summarized below in Sections 3.3.1 – 3.3.4, with summaries of the interviewee's comments.

A table, comparing the tenets of the original SEITTP concept and the current Group's activities follows this interview-based summary, after which is presented several possible future directions for the Group, with accompanying rationale.

3.3 Mission Area Fulfillment

In order to achieve its goal, as stated above, the team strives to do the following:

- Develop usable information technology and communication systems to meet end user needs.
- Demonstrate systems engineering processes that leverage best practices to maximize limited resources.
- Analyze and evaluate systems and alternatives to recognize capabilities and limitations and to maximize utility.
- Raise awareness of systems engineering via work force development and education at all levels.

The interviews addressed each of these objectives in turn. Also addressed was how well the Group is serving its core constituencies (Section 3.3.5).

3.3.1 Meeting End-user IT and Communications System Needs

Every interviewee stated emphatically that the Group is doing extremely well in this area. The best evidence for this is that sponsors routinely return to the Group with new problems, trusting that the Group will develop not just appropriate, but optimum solutions to those problems.

3.3.2 Demonstrating SE/I Best Practices to Maximize Limited Resources

Not all interviewees felt qualified to provide an opinion on this point. While all who responded to this question agreed that it was difficult to encapsulate what is meant by "best practices" (stating that they knew such when they saw it, regardless), the respondents uniformly stated that they felt the Group was implementing "best practices" in support of their promised solutions. In general, "best practices" could be defined as the integrated knowledge base a practitioner develops as a result of experience, often with reference to published standards and lessons-learned white papers and studies. One interviewee strongly emphasized the ability of the Group members to integrate applicable approaches and technologies into the Group's solutions. In practice, this means not purchasing new equipment where possible, but rather the Group depends on commercial, off-the-shelf, proven technologies where possible; taking advantage of existing infrastructure to leverage limited budgetary resources. This, in turn, requires that the Group maintain currency in knowledge and application of relevant technologies.

Two interviewees stated that the Group did not appear to be "pushing the envelope" in developing new "best practices", but that they were implementing extant practices admirably. One interviewee perceived that the Group was not applying such best practices to their own activities, owing to lack of human and financial resources, and the primary need to be directly responsive to project requirements, leaving little or no time to be self-analytical.

This having been said, however, the project manager is very clear that historical approaches, such as the much-vaunted and oft-used V-diagram model, has been or is being superseded by newer approaches that emphasize iterative, spiral-development processes. He propagates this perspective in his oversight of projects, and emphasizes such approaches when making presentations to professional audiences.

3.3.3 Analyzing and Evaluating Systems to Maximize Utility

Several interviewees had difficulty distinguishing this objective from the preceding one. As a result, there was some overlap in responses. Regardless, those who responded to this question all stated firmly that the Group was performing both systems engineering and integration activities to the clear benefit of the sponsors. As before, there was some demurral, with one interviewee stating that the Group was doing this well for sponsors, but not so well as applied to their own activities. And, as before, this was

attributed to lack of human and financial resources. Another interviewee opined that this area was being addressed well for IT projects, but felt that the Group should be extending themselves outside of the IT arena.

3.3.4 Educating and Developing the Work Force

Where interviewees considered themselves qualified to comment, all thought that significant effort was being applied to engaging students in the Group's work. Several respondents commented on practical problems associated with distinguishing between the Group's applied emphasis *vs.* the generally basic research-based activities usually associated with academic work. Such problems range from academic-year schedules vs. project schedules, to the more general applied-vs.-basic research paradigms. On the whole, however, student involvement was deemed beneficial for all parties.

Not well addressed, although implicit in earlier responses, was the degree to which the Group's activities have had an impact on practicing professionals generally, as distinct from sponsor-specific contacts, who are anecdotally uniformly satisfied with the results generated by the Group. The project manager acknowledged that he has made numerous presentations at professional society meetings, with emphasis not only on specific projects, but on the processes implemented in achieving such satisfactory results. There is evidence that the program manager, at least, is furthering the mission of systems engineering and integration to an outside audience, but entrenched conservatism within the transportation community appears to mitigate some of his attempts to do so, in that review comments on papers or presentations have included instructions to avoid discussion of processes.

A key indicator of the respect with which the Group is viewed is their having been requested to organize and manage the Western States Technology Implementers Forum, a venue that allows interested parties to come together to share experiences, and discuss common issues in implementing Intelligent Transportation Systems. Presentations have been made by the Group at this venue in years past, giving high visibility to the Group's efforts to implement and share best practices.

As regards the Group members themselves, the sense was that they had all benefited from the opportunities afforded them by dint of their being assigned to projects. These benefits range from increasing their professional knowledge bases to developing more and better tools to allow them to communicate with sponsors and within the Group.

3.3.5 Service to Constituencies

Largely on the basis of a summation over all previous responses, but with an admixture of specific comments, the interviewees felt strongly that the Group was responding well to its core constituencies (i.e., transportation-related groups), and that these groups provided follow-on work was testimony to their satisfaction with the Group's support.

3.4 Planned vs. Actuals: The Original SEITTP Concept and the Group's Implementation

To determine how well the Group as implemented embodies the precepts brought forth in the original SEITTP "Center of Excellence" document, referred to earlier, the original SEITTP draft concept document was parsed into core areas that formed the underpinnings of the operational approach. These core areas were then mapped to cognate Group activities, with differences and/or similarities between the two noted.

[N.B.: Owing to similarity in analysis across the several sections addressed, there is some duplication of text in the *Commentary* sections. This is intentional.]

3.4.1 SEITTP Focus Area Concept: Education – The original document put forth the tenet that the Program should provide work force development and continuing education opportunities in systems engineering and integration for transportation professionals. It will promote systems engineering and integration training as part of the undergraduate and graduate engineering curriculum, and will provide students with the opportunity to apply what they've learned in the classroom to "real-world" problems.

3.4.1.1 SEDIG Implementation - Opportunities for both graduate and undergraduate students are provided. These opportunities provide real-world, hands-on learning environments.

While there have been opportunities to provide input to graduate (master's) theses, the program manager having been involved in three of these, there is no clear integration with curriculum development *per se* within the COE.

3.4.1.2 Comparative Analysis - The Group activities provide student opportunities, but there have been limited continuing education opportunities for professionals already engaged in relevant work, despite the program manager's efforts to share the benefits of the Group's experience, particularly as regards process. Such limited incursion appears largely due to entrenched conservatism in the transportation community generally.

The SEITTP concept addressed SE/I opportunities in a very general sense, i.e., for advanced transportation technologies, yet the Group focus is virtually entirely on information technologies.

3.4.1.3 Commentary - At least three interviewees (but not Group members) acknowledged that when they think of SE/I, they think in terms of systems generally, and that IT and communications are subsets of larger systems, against which SE/I processes could be brought to bear.

Most WTI staff, however, stated that the IT-centric view is that of the U.S. Department of Transportation, and so that is their emphasis.

Given the degree to which the Group takes its lead from the program manager, whose background is in IT and related areas, this centrism is not unexpected.

If, as noted below and elsewhere, the Group were to broaden its focus, there would be many more opportunities to work with more faculty members in more departments in the CoE, both as regards projects and curricular integration.

3.4.2 SEITTP Focus Area Concept: Research - Providing multidisciplinary transportation-related research and development opportunities for engineering and science faculty, staff and students, and will use and promote WTI, COE and other MSU labs and facilities for systems integration efforts. It will use technology transfer and the publishing of research results to promote the application of transportation-related research in systems engineering and integration.

3.4.2.1 SEDIG Implementation - Historical and ongoing Group projects address advanced information technologies as applied to transportation problems. The outcomes clearly benefit the sponsors and are responsive to their needs and requirements.

There is some partnership and collaboration with MSU COE faculty. Presentations—either as lectures at MSU venues or at professional society/group meetings of historical and ongoing projects appear to be limited, owing to other demands on the project manager's time (as he has primary responsibility for such communication), or because of lack of overlap of interests (in the case of COE departments).

3.4.2.2 Comparative Analysis - The SEITTP concept was predicated on there being a large number of partnerships and collaborations between WTI/SEDI Group members and COE faculty. The reality is that the number of these is relatively few as regards projects, and even fewer as regards the number of faculty and departments involved, despite the apparent early buy-in by faculty during the formative SEITTP discussions.

With the emphasis on technology development, and the observed lack of writing skills on the part of Group staff, there appears to be only a small amount of technology transfer per se (other than deliverables to the sponsors). The program manager does make attempts in this direction, and with some success, with some development and promulgation of process advances.

3.4.2.3 Commentary - At least three interviewees (but not Group members) acknowledged that when they think of SE/I, they think in terms of systems generally, and that IT and communications are subsets of larger systems, against which SE/I processes could be brought to bear.

Most WTI staff, however, stated that the IT-centric view is that of the U.S. Department of Transportation, and so that is their emphasis.

Given the degree to which the Group takes its lead from the program manager, whose background is in IT and related areas, this centrism is not unexpected.

If, as noted below and elsewhere, the Group were to broaden its focus, there would be many more opportunities to work with more faculty members in more departments in the CoE.

3.4.3 SEITTP Focus Area Concept: APPLICATION - Supporting the development of emerging transportation technologies, and assisting to evaluate and implement state-of-the-art technology, evaluating existing conceptual design products under actual use conditions, and developing and providing best management practices for integration of these technologies.

3.4.3.1 SEDIG Implementation - The Group is clearly applying best management practices to choices of technologies to address sponsors' requirements and to develop applicable and useful solutions thereto. COTS technologies and existing infrastructure are routinely employed where possible, and new technologies are implemented only when existing solutions are not responsive.

3.4.3.2 Comparative Analysis - The Group addresses this focus area very well, with the caveat that their activities are almost entirely IT-centric.

3.4.3.3 Commentary - At least three interviewees (but not Group members) acknowledged that when they think of SE/I, they think in terms of systems generally, and that IT and communications are subsets of larger systems, against which SE/I processes could be brought to bear.

3.4.4 SEITTP Focus Area Concept: WTI POSITIONING - Positioning WTI to be better able to effectively address the transportation challenges that rural and small urban areas present.

3.4.4.1 SEDIG Implementation – A key manifestation of the Group's utility is its expertise in the increasingly acknowledged niche area of rural transportation issues. Rural areas present transportation challenges that are unique; responses to large urban challenges are not easily transferred to rural areas, especially in the communications realm.

3.4.4.2 Comparative Analysis – The Group addresses this focus area very well, with the caveat that their activities are almost entirely IT-centric.

3.4.4.3 Commentary - At least three interviewees (but not Group members) acknowledged that when they think of SE/I, they think in terms of systems generally, and that IT and communications are subsets of larger systems, against which SE/I processes could be brought to bear.

3.4.5 SEITTP Focus Area Concept: ATTRACTING STAFF - Attracting a high-quality engineering and scientific staff to Montana State University.

3.4.5.1 SEDIG Implementation – One interviewee commented that it was the presence of and access to WTI (generally) that influenced his decision to accept a position in the COE at MSU. No other data were sought.

3.4.5.2 Comparative Analysis – The staff at WTI (a MSU exponent) is of high quality and professionalism, but it is was not within the purview of this task to determine the extent to which WTI's reputation caused its staff to choose a position at WTI specifically.

3.4.5.3 Commentary – No comments.

3.4.6 SEITTP Focus Area Concept: REGIONAL INFRASTRUCTURE - Creating a stronger research infrastructure available to many organizations in Montana and neighboring states.

3.4.6.1 SEDIG Implementation - The Group's professionalism is clear, and the sum total of their body of work clearly shows the strength of and potential for WTI generally (and the Group, specifically) to augment the region's infrastructure in relevant disciplines.

3.4.6.2 Comparative Analysis – At least two interviewees commented that there are likely significant opportunities for the Group both within the state and the surrounding region. Explicit statements were made that inroads into cognizant organizations was not as deep as it could be.

3.4.6.3 Commentary – No comments.

3.4.7 SEITTP Usage Scenarios - Given the breadth of usage scenarios offered in the draft concept document as having potential for the SEITTP, there is little utility in a detailed analysis and comparison of those scenarios vs. projects addressed by the Group, given the small size of the extant Group. Those scenarios speak to a wider range of potential SE/I-related activities than the IT- and communications-centric choices made by the group. The current consultant takes this disconnect to support his contention that the SEDI Group has at least the potential for a far wider range of possible projects than currently being addressed, and that the SEITTP concept was

formulated with this wider range in mind. Details of this contention and supporting rationale will be presented in Section 3.5.

3.5 Conclusions from the SEITTP Concept vs. SEDIG Implementation Analysis

Given that the Group formed in, basically, an *ad hoc* fashion, but always with an eye toward providing systems engineering, development, and integration support to its sponsors, it should not be surprising that there is considerable overlap between its current implementation and the concepts and precepts brought forth in the original SEITTP concept document.

However, given that the original concept document addressed a far larger suite of possible activities, suitable for handling by a larger organization—the "Center of Excellence—it should similarly not be surprising that the current Group's activities focus on only subsets of the original concept.

Summarizing:

- **Education:** The Group's projects provide significant opportunity for students, although the opportunities could be increased if there were better integration with CoE faculty (see *Research,* following)
- **Research:** Owing largely to the limited areas of overlap between Group interests and those of CoE faculty in several departments that might otherwise be considered, research is not as broad as it could be.
- **Application:** The Group implements best practices, and provides the best balance between budget and application, using appropriate technologies to solve sponsors' problems.
- **WTI Positioning:** With its clearly rural focus, the Group has limited opportunity to address urban problems. This is further exacerbated by its geographical location.
- **Attracting Staff:** Due largely to its dependence on soft money and—to a certain extent—its geographical location, it is difficult to attract additional highly qualified staff.
- **Regional Infrastructure:** The Group is having significant success in several geographical areas, but may not be making the state and regional inroads that are hoped for.

Overall, then, the Group does what it does very well, but does not function at the level expected of a "center of excellence". Whether or not it is appropriate for the Group to move in such a direction is subject to points raised in the next section, which offers several potential futures for the Group.

3.6 Potential Futures

Future possibilities for WTI's Systems Engineering, Development, and Integration Group depend on the need for high-level decisions concerning the vision the WTI and College of Engineering administrations have for the Group. The task is further complicated by the observation that the role of the Group is still—as it was early on in the SEITTP feasibility study process—open to interpretation. In this latter regard, it must be decided if the Group is worthy of being a separate program (or focus area), or if it is to serve a support role for the other initiatives. Whichever direction is chosen, there will be budgetary consequences. If it is to further grow and develop as a separate initiative, then a means for securing its financing is necessary, as the constant search for soft money is sapping some of the strength of the Group. Even if it is relegated to a purely support role, then funds to engage its resources must be obtained by the other program areas, if only to have a fund and budget number against which the Group can charge for its support.

More than this, however, is the question of where the technical focus of the group should be. As currently constituted, it is almost (but not entirely) IT- and communications-centric. As noted earlier, given DoT's traditional evaluation of SE/I as being IT focused and the Group leader's own IT and communications focus, this is a natural outgrowth of its origins and the work it has been able to draw in since its inception. But, as noted earlier, there are many in the larger technical community who see SE/I as having applications far wider than information technologies, no matter how advanced they may be.

Another related area that should be addressed is the prospect of providing more than prototypes as solutions. Several respondents noted that sponsors often seem to want more than the prototype; they want fully fieldable solutions. To provide this requires that a manufacturer be found to produce often small runs of field-tested and proven solutions. Currently, the Group has no such connections, nor does it take into account manufacturing requirements in its designs—requirements that could dictate solutions other than those that result in prototypes. Regardless of what direction the Group moves, this kind of connection and insertion of manufacturing requirements should play a larger role if the Group is to be maximally responsive to a wider range of constituencies. The program manager is aware of the increasing importance of such an approach to sponsors, and argues that such a move is a natural evolutionary next step, in that sponsors' early requirements emphasized prototype generation. This is an issue in a state of flux, and the subject of discussions within WTI generally.

Keeping this requirement in mind, herewith are presented several possible scenarios for possible futures for the Group, all of which should incorporate the manufacturing boundary conditions. The options presented here are offered as indicative of possible futures. Please note that no opinion is provided as to which is the "best" direction for the Group. Rather, more input from higher-level strategic planning activities is needed before a specific recommendation could be made.

3.6.1 Basic Option I: More of the Same

Given the clear success of the Group in addressing primarily IT-type projects for its sponsors, continuing along the current trajectory is an easy path to follow. This is not to minimize the difficulties that lay ahead of the Group: The lack of more-senior staff, limited financial and human resources, and the heavy reliance on the program manager will continue to be problematical. Such problems would be fewer than those associated with the other options to be discussed below, but maintaining the IT focus, depending on existing sponsors, and maintaining a low level of participation with COE faculty is a relatively safe place to be.

Assuming the acquisition of additional work within this framework, the ongoing, well-earned success of the Group would likely continue, but this option does not allow for much further growth or development.

3.6.2 Basic Option II: Expanding Breadth

A slight variant of the status quo that could generate more work (and associated funding) is to attempt to find additional sponsors. The more sponsors there are, the more financial resources would be available, thereby allowing the size of the team to increase. Under narrow but plausible conditions, the additional funding could also allow more senior staff to be hired, along with a co- or deputy program manager to help the program manager by offloading some of the management and technical work, including the need for written and oral communications. To a first approximation, additional sponsors could come from any organization—from the local, state, and regional levels through national and, conceivably, international groups that deal with transportation.

3.6.2.1 Center of Excellence in SE&I (IT only)

Mooted in early presentations to the COE faculty and associated planning documents was the concept of a “Center of Excellence” in SE/I, emphatically with emphasis on IT, as that is how the transportation community views SE/I. This direction is a natural evolution of expanding the breadth of the existing group.

As currently constituted, formation of such a Center seems unlikely, owing to the relative professional immaturity of the Group’s staff and the other limitations described elsewhere, the group’s obvious successes and relatively unique expertise in rural applications notwithstanding.

Implicit in the concept of a Center of Excellence is a core group of professionals with significant experience and applicable expertise, around which would coalesce several concentric rings of interested parties, and extensions out into a very widely ranging community. Often explicit in universities’ (and agencies’) criteria for Center of Excellence status is a heavy emphasis on research, both basic and applied. The

current Group does a fine job with finding or inventing solutions, but is not at all well-placed to push the edge of the envelope in new SE/I processes and procedures, nor in communicating either its current practices or potential new ones to a wider community, the program manager's efforts to do this notwithstanding. Some of this could be mitigated by tighter integration with and participation of COE faculty, both as to larger numbers of faculty from departments already working with the Group, and a larger number of departments similarly involved.

Further, some source of funding would be required that would move the Group out of its current stultifying dependence on soft money. Herein lies a Catch-22: To attract programmatic funding would require that there be a hard-core cadre of staff (with a heavy emphasis on senior practitioners), capable of doing both basic and applied research, and a portfolio of successful projects that clearly shows that a large(r) Center-sized group can acquire and handle such projects. On the other hand, such a group cannot be formed without significant programmatic funding.

Regardless, were it practical to form such a center, the many laudatory sample projects outlined in the original SEITTP concept document would be well within reach, with concomitant potential to grow a center of excellence in the directions summarily discussed in Section 3.6.3, below, depending on the time horizon applied to this strategic planning activity. A consequence of such positioning is that the opportunities for attracting additional work from a more varied number of potential customers increases significantly.

3.6.2.1.1 Possibilities for Other Center Types

The statements above apply also to the possibilities that had been raised in the original SEITTP concept for the formation of an Engineering Research Center (ERC) or the organization of an Integrative Graduate Engineering and Research Training (IGERT) group, but the strictures are even more constraining when attempting to generate a competitive proposal for their cognate programs.

Both ERCs and IGERTs call for significant integration of capabilities provided by their supporting organizations, i.e., the location of the center itself, supporting organizations, etc.; clearly defined research programs (usually with an emphasis on basic research, but applied is not unknown); integration of research areas with established and new or to-be-developed curricula; novel means of management across the various disparate entities; clear informal education and outreach plans; plans for attracting underrepresented minorities; and more. Given the current track record with respect to engaging solely with a limited number of COE representatives in a small number of departments; the remoteness of WTI and the attendant potential difficulty in attracting additional stellar and minority professionals and students; and the lack of any evidence of curricular integration (i.e., hands-on work augmented by specific formal coursework (or vice versa)), ERC and/or IGERT formation seems a remote possibility.

3.6.3 Advanced Option: New Directions

As noted earlier, how one defines SE/I depends upon where one is accustomed working. For those with a transportation focus, and decidedly those within the current Group and the WTI executive director, this explicitly means IT and communications centrism. For almost everyone else, however, SE/I has a wider range of applicability. It is clear that the tools and approaches as currently implemented in the Group are appropriate and used to best advantage in the IT arena.

However, by expanding the breadth of activity (i.e., IT focus, but with more clients, now both within and outside of the transportation community), and by developing and expanding the depth of the Group's activities (i.e., developing more and better tools, processes, and procedures for SE/I across many foci in the solution space) takes the Group and WTI in entirely new directions, fraught with uncertainties and with significant competition from established groups, both within and outside of the transportation realm.

It is important to note that virtually every interviewee saw benefits in moving the Group's activities beyond the IT and communications realm, and were excited by the possibilities. But they also saw the difficulties in moving beyond IT, as that is where the current focus is, both for them and their own areas of expertise, and the emphasis being put on the types of projects being made available to them by current sponsors.

3.6.3.1 IT- and Communications-specificity vs. SE&I Generally

As has been mentioned several times in this document, applying SE/I processes and procedures is not necessarily limited to the IT and communications domains. While it has significant utility there and, as such, of particular application to transportation problems and their solutions, many (if not most) engineers do not see IT and/or communications as the prime foci. Indeed, SE/I can—and should—be thought of as a generalizable set of tools that can be applied to *any* system, which includes systems of systems.

By making this kind of conceptual leap, one may easily see that problems may be attacked in a holistic fashion, one that is far more encompassing than the IT- and communications-centric focus as practiced by the current Group. Such systems can become huge—almost intractable—but it is then up to the systems engineers to work tightly with clients/customers to define the limits thereof, and then to apply best practices across a wide range of disciplines to integrate suitable technologies and approaches to develop tractable, affordable, applicable, and—one hopes—expandable systems that are responsive to the original problems. Such responses cannot be thought of as complete end-points. Rather, they must be designed in such a way as to allow further growth and development, building on those initial (and follow-on) solutions.

To do this in any reasonably disciplined fashion requires input from many different areas of expertise, beginning at the requirements-gathering and -definition stages of SE. The kinds of problems that could be addressed by this widely cast net approach becomes

far larger than even the largest IT- and communications-centric problems. There is clearly still a role for IT and communications in solutions for many of these problems, but it becomes only a part, rather than the whole.

Such an approach fits well with the COE's approach to training the future workforce, as outlined in the Summer 2007 "Message from the Dean" (http://www.coe.montana.edu/message_from_dean.html), wherein Dean Marley refers to the National Academy of Engineers concept of the "engineer of 2020", and MSU's response as the "MSU Engineer of 2010". This concept emphasizes multidisciplinary design and—as practiced by other universities, the need to create the "multi-dimensional engineer" or "trans-disciplinary engineer", resulting in the Boeing Corporation concept that they expect their engineers to be "systems integrators". As Dean Marley said, "In general, this means that they better understand the business environment, technical trade-offs in complex product or system design, and even that they appreciate entrepreneurship."

3.6.3.1.3 Center of Excellence in SE&I (All systems)

These same precepts and approaches can (and should) be applied to the Group in whatever incarnation is ultimately deemed optimal, to the benefit of the Group and, ultimately, to its clients. But it is in the realm of a holistic, cross-system approach to the implementation and application of SE/I principles and processes that its true value comes to the fore.

With such a widened mandate, the Group's growth into a true Center of Excellence in SE/I absolutely requires a strong team of multi-, inter-, and cross-disciplinary engineering solutions to problems. The opportunities for such teams to cross-pollinate its members would clearly increase the value of the individual for future work, regardless of the discipline, or the professional level. Everyone, from students onward, would continue to learn and increase their skill set, not only in technical areas, but in ways that would accommodate Dean Marley's admonition to understand business, have a wider view of potential solutions, and open doors for entrepreneurial activities.

There are many issues that must be dealt with in approaching such a goal. There must be significant buy-in on the part of many faculty members across many COE faculty (and, likely, those from other colleges within MSU) to develop research programs and curricula that are directly responsive to such a mandate. New and creative methods of teaching and optimizing organizational dynamics across many stakeholders must be developed and implemented. Further, inroads must be made with high-quality organizations in the private sector to further leaven the mix.

Programmatic funding is a *sine qua non* of any such organization.

The challenges facing the Group specifically, and WTI and the University generally, also include the current make-up of the group, whose focus is—owing to the way the Group was formed, how it developed, and how it has been led—clearly in the IT camp. It is possible that the program manager (whose experience is in CS and IT, and who has

shown definite expertise in SE/I in this area) has the wherewithal to lead an organization with such a broadened scope. Were this to be the case, it is increasingly imperative that some new form of management structure be implemented, as the program manager is already suffering from the number of responsibilities he manages.

From a more distant perspective, the question must be asked, would such a center fit under the general rubric of WTI? Or, is this something that the University would want to establish as a separate organization, one that would tap a SEDI Group within WTI, whose core competencies would remain IT-centric and transportation-focused?

3.7 Concluding Remarks, Task 5

3.7.1 "Center of Excellence" Philosophy - The original SEITTP study had as a prime focus the prospect of developing a "center of excellence" in systems engineering and integration as applied to transportation issues. The information elicited in Task 4 and the analysis of possible futures for the Group, as embodied in Task 5, have brought several issues to the fore. These issues reduce to several easy-to-ask questions.

(1) Should the group keep its current size and make-up, continuing to service its current core sponsorship?
(2) Should the group expand its size and make-up as a means of expanding its customer base, but still within the transportation rubric?
(3) Should the group broaden and deepen its make-up in an effort to attract customers/sponsors outside the transportation realm?
(4) Should the group develop a stronger, more academic research profile, necessary to organize a true "center of excellence" in systems engineering and integration?

Distributed across all these questions is a key question, the response to which will depend on which route is chosen:

Where is the most help needed (i.e., technical; management; development)?

The answers are not as easy to develop.

A distinction that may help in making such decisions is the difference between science and engineering.

Science in this context is meant to describe an approach to a discipline that emphasizes asking basic questions, albeit with an eye toward ultimately applying new knowledge that arises from such activities.

Engineering in this context is meant to describe a suite of activities that is eminently applied to solving specific problems, albeit with a lessons-learned component that would

allow generalizing approaches across a wide range of problems. There is definitely a research component to engineering, but it is *applied* research, i.e., problem-specific.

If a true "center of excellence" is the desired target, then there must be a "scientific" component, one that—by design—furthers the disciplines of systems engineering, looking for newer and better ways to define and understand user requirements, and to translate them into workable solutions. It also means developing new and better ways to allow optimum integration of components into those solutions. This hearkens back to the earlier discussion of, "What are 'best practices'?" This, in turn, entails research into the nature of such practices, and developing metrics to clearly define "best".

The results of such "basic" research would then be integrated into the applied arm of the center, with concomitant feedback between the two arms, such that the theories developed in the "science" arm are applied in the "engineering" arm, and the results of those applications fed back to the "science" arm. This process is the essence of systems engineering and integration. The ability to successfully apply such tools to the activities of the organization itself is, perhaps, the best metric, as it should result in a positive feedback loop, one that generates more and more-satisfied customers.

WTI and the COE may be in a position to accomplish this, but it would require that the Group broaden its activities outside the IT and communications realm, although the focus of the center could remain in transportation, with one caveat: The principles and processes that would be developed in such a center would have significant generalizability, and could allow for growth into areas outside transportation issues. This, then, requires significant consideration on the part of the university of exactly what it wants such a center to accomplish, and how it would fit into the university's larger strategic mission.

3.7.2 Philosophy in Practice – The exposition of the preceding section aside, it is very clear that the Group as currently implemented performs admirably. Its internal and external interfaces and activities are providing significant service to its sponsors, and the members are highly respected by their peers and their customers.

The Group's activities are clearly in keeping with the basic tenets of the original SEITTP concept, differing only in terms of scope and range of potential activities. The members are consummate professionals with a combined broad range of expertise and experience that are brought to bear with a sterling track record of satisfying their sponsors, employing best practices throughout their activities.

As noted above, while it is this writer's opinion that without significant focus and structural changes the Group is likely not well positioned to be a true "center of excellence" in SE/I, they could grow and form an increasingly viable, visible, and valuable focus (i.e., "center", in a general sense) for practical SE/I activities generally, providing education and assistance to the transportation community and, potentially, to an even wider range of interested groups.