Greater Yellowstone Rural ITS Priority Corridor Project

Tasks 6, 7, and 8
Regional Architecture Development

Prepared for:

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IMPLEMENTATION STATEMENT

This study is sponsored by the Montana Department of Transportation in cooperation with the U.S. Department of Transportation, Federal Highway Administration. The major objective of this report is to develop and define the necessary architecture elements for the Greater Yellowstone Rural ITS (GYRITS) Priority Corridor Regional Architecture. The development of this regional architecture will enable effective implementation of ITS solutions within the Greater Yellowstone region.

DISCLAIMER

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EXECUTIVE SUMMARY

This report describes the essential elements of a regional architecture, including priority rural market packages, geographic areas of focus, measures of effectiveness, and communication alternatives for the region. In doing so, this report also outlines the process of developing a regional architecture, including modifying the National System Architecture (NSA) to accommodate the rural aspects of the Greater Yellowstone Rural ITS (GYRITS) Corridor.

The specific Corridor challenges, as identified through stakeholder interviews, safety data analysis, Geographic Information Systems (GIS), and a regional traveler needs survey, are related to priority rural market packages. These market packages are rural in scope and definition and consist of deployable technologies that address the region's transportation challenges.

The architecture development process followed for this effort is shown in Figure i. The resulting market packages mapped to the rural Critical Program Areas (CPAs), as defined by the Advanced Rural Transportation Systems (ARTS) Program, are contained in Table i.

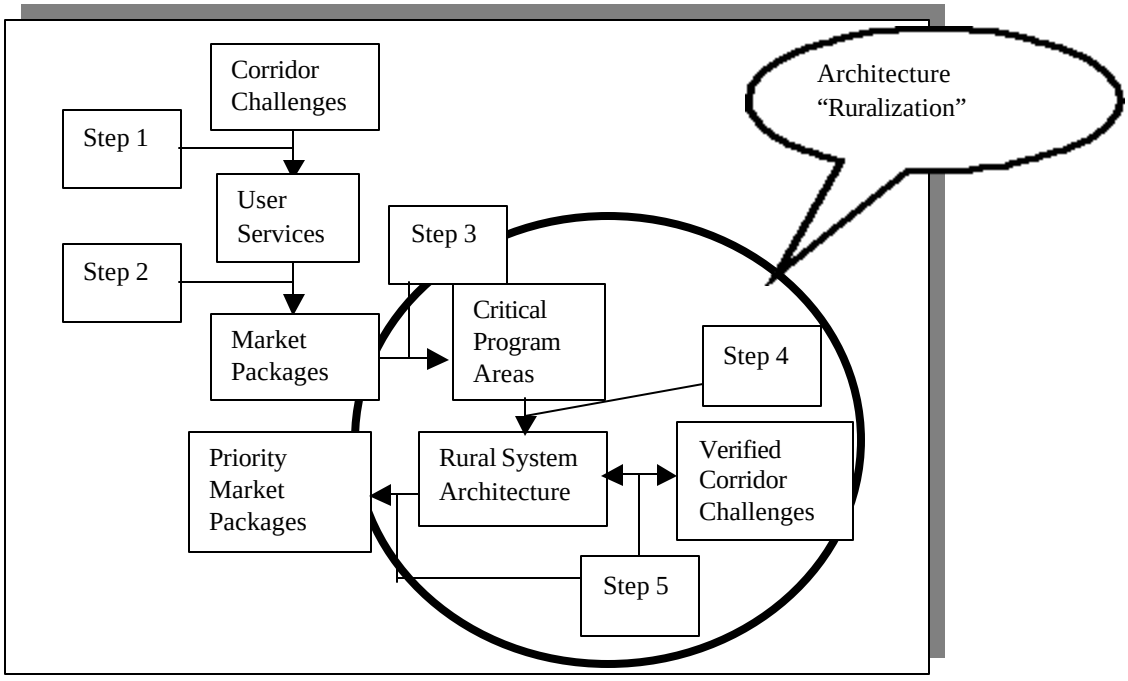

Figure i: Architecture Development Process

Table i. Summary of GYRITS Priority Market Packages

Critical Program Areas / Market Packages	Traveler Safety and Security	Emergency Services	Tourism and Travel Information Services	Public Traveler Services/Public Mobility Services	Commercial Vehicle Operations	Infrastructure Operations and Maintenance	Fleet Operations and Maintenance
INCLEMENT WEATHER CHALLENGE							
Broadcast Traveler Information			√			√	
Interactive Traveler Information			√				
Network Surveillance	√					√	
Probe Surveillance						√	
Safe Speed Advisory	√				√		
Traffic Information Dissemination	√		√			√	
UNSAFE SPEED CHALLENGE							
Dynamic Warning System	√						
Mobile Traffic Management/Enforcement	√						
Safe Speed Advisory	√				√		
Traction Control	√						
COMMERCIAL VEHICLE SAFETY CHALLENGE							
CVO Fleet Maintenance					√		√
Driver Safety Monitoring	√				√		√
Mobile Traffic Management/Enforcement	√						
On-board CVO Safety					√		√
Roadside CVO Safety					√	√	√
Weigh-in-motion					√	√	
HAZARDOUS MATERIALS CHALLENGE							
HAZMAT Management					√	√	√
Incident Management System	√					√	
Mobile Traffic Management/Enforcement	√						
EMERGENCY RESPONSE TIME CHALLENGE							
Emergency Response	√	√					
Emergency Routing		√					
Incident Management System	√					√	

Table i. Summary of GYRITS Priority Market Packages (Continued)

Critical Program Areas / Market Packages	Traveler Safety and Security	Emergency Services	Tourism and Travel Information Services	Public Traveler Services/Public Mobility Services	Commercial Vehicle Operations	Infrastructure Operations and Maintenance	Fleet Operations and Maintenance
EMERGENCY RESPONSE TIME CHALLENGE (Continued)							
Mayday Support	√	√					
Virtual TMC		√				√	
TRAVELER/TOURIST INFORMATION CHALLENGE							
Broadcast Traveler Information			√			√	
Interactive Traveler Information			√				
Network Surveillance	√					√	
Probe Surveillance						√	
Virtual TMC		√				√	
Yellow Pages and Reservation			√				
FAILURE TO YIELD RIGHT-OF-WAY/DISREGARD FOR TRAFFIC CONTROL CHALLENGE							
Intersection Collision Avoidance	√						
Mobile Traffic Management/Enforcement	√						
REAR-END COLLISION CHALLENGE							
Driver Visibility Improvement	√				√		
Intersection Collision Avoidance	√						
Intersection Safety Warning	√						
Pre-Crash Restraint Deployment	√						
ANIMAL ENCROACHMENT ON THE ROADWAY CHALLENGE							
Animal-vehicle Collision Countermeasures	√						
Lateral Safety Warning	√				√		
Longitudinal Safety Warning	√				√		
SNOWMOBILE CRASH CHALLENGE							
Dynamic Warning System	√						
Intersection Collision Avoidance	√						
Lateral Safety Warning	√				√		
Longitudinal Safety Warning	√				√		

Table i. Summary of GYRITS Priority Market Packages (Continued)

Critical Program Areas / Market Packages	Traveler Safety and Security	Emergency Services	Tourism and Travel Information Services	Public Traveler Services/Public Mobility Services	Commercial Vehicle Operations	Infrastructure Operations and Maintenance	Fleet Operations and Maintenance
COMMERCIAL VEHICLE EFFICIENCY CHALLENGE							
CVO Fleet Maintenance					√		√
Electronic Clearance					√	√	√
Electronic Clearance Enrollment	√				√		√
Fleet Administration					√		√
Freight Administration					√		√
Vehicle Tracking and Dispatch					√		√
Weigh-in-motion					√	√	
TRAVELER MOBILITY CHALLENGE							
Demand Responsive Transit Operations				√			
Dynamic Ridesharing			√	√			
Multimodal Coordination							√
Traffic Information Dissemination	√		√			√	
Transit Fixed-Route Operations				√			√
Transit Passenger and Fare Management				√			√
Transit Vehicle Tracking							√
Vehicle Tracking and Dispatch							√
YELLOWSTONE NATIONAL PARK ENTRANCE CONGESTION CHALLENGE							
Facility Use/ Parking Fee Management			√				
Mobile Traffic Management/Enforcement	√						
Traffic Information Dissemination	√		√			√	
Transit Fixed-Route Operations							√
CONSTRUCTION ZONE CONGESTION CHALLENGE							
Mobile Traffic Management/Enforcement	√						
Traffic Information Dissemination	√		√			√	
TOURISM AND ECONOMIC DEVELOPMENT CHALLENGE							
Facility Use/ Parking Fee Management			√				
Transit Passenger and Fare Management							√

Table i includes several new or modified market packages that were created to meet specific challenges. These new market packages were created using solution technologies that are already available to facilitate infrastructure deployment. The modified market packages were changed to be rural in scope and compatible with applicable challenges. These new market packages include the following:

- Animal-vehicle Collision Countermeasures
- Dynamic Warning Systems
- Emergency Vehicle Maintenance
- En-route Interactive Traveler Information
- Pre-trip Interactive Traveler Information
- Regional ITS Planning
- Roadside Traveler Information
- Safe Speed Advisory
- Safety for Commercial Vehicles
- Transit Vehicle Routing
- Vehicle Tracking and Dispatch

Rural ITS implementation within the Corridor will be heavily dependent on communication technology availability and alternatives. The feasibility of various communication technologies depends on the existing communications infrastructure within the Corridor as well as geographic constraints. Available communications technology, the type and extent of existing infrastructure, and the requirements of the individual ITS applications, are reviewed within this report to help identify and facilitate feasible implementation of ITS infrastructure and identify potential projects. Both wireless and wire-line communications were reviewed, with a discussion of range, signal, and transmission options. Table ii contains the viable communication options for each of the corridor challenges.

Table ii. Viable Communication Alternatives

CORRIDOR CHALLENGES	COMMUNICATION ALTERNATIVES						VIABLE TECHNOLOGY ALTERNATIVES																		
	Wire-line	Wireless	One Way	Two Way	Short-range	Long-range	Microwave Beacons	Infrared Beacons	RF Beacons	AM Radio	FM Radio	Area Radio Networks	HAR	TV	Cellular	FM Sideband	Direct Broadcast Satellite TV	Serial Wire-line RS 232	Telephone Lines	Coaxial Cable	Fiber Optic	Cable TV	Internet and On Line Services	Packet Data Radio	Spread Spectrum Radio	Trunked Radio Systems
Inclement Weather	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√			
Unsafe Weather	√	√	√		√		√	√	√	√	√				√	√		√	√	√	√					
Safety Problems Relating to Commercial Vehicles	√	√	√	√	√	√	√	√	√	√	√				√	√		√	√	√	√			√	√	√
Hazardous Materials	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√			
Emergency Response Time	√	√	√	√		√	√	√	√		√	√	√	√	√	√		√	√	√	√				√	√
Lack of Traveler/Tourist Information	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√		√	√
Failure to Yield Right-of-way or Disregard for Traffic	√	√	√		√	√	√	√	√						√	√	√	√	√	√	√					
Rear-End Collisions		√	√	√	√		√	√	√																	
Animal Encroachment on the Roadway	√	√	√	√	√	√	√	√	√				√		√			√	√	√	√					
Snowmobile Conflicts	√	√	√	√	√	√	√	√	√				√		√			√	√	√						
Commercial Vehicle Efficiency	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√		√	√	√	√		√	√	√	√
Traveler Mobility	√	√	√	√		√				√	√	√	√	√	√	√	√		√	√	√	√	√			
Congestion at Yellowstone National Park Entrances	√	√	√	√	√	√	√	√	√	√	√	√	√	√		√	√	√	√	√	√	√	√			
Congestion at Construction Zones	√	√	√		√	√	√	√	√	√	√	√	√	√		√	√	√	√	√	√	√	√			
Tourism and Economic Development	√	√	√	√	√	√	To Be Determined																			

The information contained in this report will support various future tasks in the GYRITS Priority Corridor Project. These include the following:

- Preliminary project identification and evaluation (Task 9),
- Preliminary project deployment (Task 10),
- Define regional architecture (Task 11),
- Develop ITS systems architecture and operations report (Task 12), and
- Evaluate systems and produce final report (Task 13).

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INTRODUCTION

With its diverse geographic, climatic, demographic, and topographic characteristics, the Greater Yellowstone Rural Intelligent Transportation Systems (GYRITS) Priority Corridor presents several challenges and opportunities to better the region's transportation network using ITS. The use of ITS to address many of these challenges will help to increase the safety, efficiency, and quality of travel within the GYRITS Corridor. Without proper planning through the development of a regional ITS architecture, the diversity of Corridor attributes could challenge the application of ITS solutions and their associated communication technologies.

This report describes the essential elements of a regional architecture, including priority rural market packages, geographic areas of focus, measures of effectiveness, and communications alternatives for the region. In doing so, this report also outlines the process of developing a regional architecture, including modifying the National System Architecture (NSA) to accommodate the rural aspects of the GYRITS Corridor.

Background

Transportation challenges specific to the GYRITS Corridor, in combination with the current project's goals and objectives, play a very important role in developing the GYRITS Corridor Regional Architecture. The specific corridor challenges help to identify what the system will have to address to be effective. Project goals and objectives help to identify what can be expected from the technologies being deployed. A review of GYRITS Corridor challenges and project goals and objectives is provided in this section.

Once the Corridor challenges are identified and the project goals and objectives are defined, the task of developing the GYRITS Corridor Regional Architecture begins. A review of the NSA and the elements that make up a regional architecture is necessary to facilitate understanding of the various architectural "building blocks" of ITS. This section provides an overview of architecture concepts and considerations.

Review of Corridor Challenges and Geographic Areas of Focus

Corridor challenges and traveler information needs were determined through previous *GYRITS Priority Corridor Project* tasks, which included:

- stakeholder outreach to identify perceived challenges and define Corridor goals (Task 3),
- data collection and analysis to quantify challenges and identify geographic areas of focus (Task 3), and
- a rural traveler needs survey to identify traveler information needs within the Corridor (Task 4).

Task 3 clearly identified Corridor challenges and geographic areas of focus. The Corridor challenges identified in Task 3 included:

- inclement weather,
- unsafe speeds,
- commercial vehicle safety,
- hazardous materials,
- emergency response times,
- lack of traveler/tourist information,
- failure to yield right-of-way or disregard for traffic control,
- rear-end collisions,
- animal encroachments on the roadway,
- snowmobile crashes,
- commercial vehicle efficiency,
- traveler mobility,
- congestion at Yellowstone National Park entrances, and
- congestion at construction zones.

The challenges of inclement weather and unsafe speed were combined in Task 3 to create a category aligned with slippery roads and speed too fast for conditions. In this report, these two challenges will be separated again due to the distinct manner in which the challenges will be addressed through potential solution technologies.

Some of the challenges within the GYRITS Priority Corridor are Corridor-wide; others are location-specific. Where possible, geographic areas of focus were determined for each challenge using Geographic Information Systems (GIS). These areas of focus are summarized in Table 1.

Through examining the different Corridor challenges and their respective geographic areas of focus, the challenges faced when attempting to implement ITS become apparent. The mountainous areas within Yellowstone National Park and the Gallatin Canyon present significant communications and power supply challenges.

Through the efforts in Tasks 3 and 4, Corridor challenges were identified and discussed in detail. These Corridor-specific challenges will help to shape the scope of GYRITS Corridor Regional Architecture by directing the focus on particular "market packages" (discussed later in this section).

Review of Project Goals and Objectives

GYRITS Priority Corridor project goals and objectives will also help to shape the regional architecture and facilitate project identification. Initial project goals sought to:

- increase safety,
- improve emergency response,
- improve commercial vehicle operations,
- increase travel information and trip enhancement,
- improve interagency communications,
- reduce congestion, and
- increase economic activity.

Table 1. Geographic Areas of Focus

Inclement Weather	Regional, travel impacts due to severe winter weather are Corridor-wide.
Unsafe Speed	Regional, several areas within the Corridor have restrictive horizontal alignment, drivers over-driving the abilities of their vehicle and their skills are a problem throughout the Corridor.
Safety Problems Relating to Commercial Vehicles	Area-specific, of primary concern in the mountain passes in the Corridor, three geographic locations have been identified such as US 191 through Gallatin Canyon.
Hazardous Materials	Regional, transport of hazardous materials is a very environmentally sensitive topic throughout the Corridor, due to a moratorium on transport through YNP, portions of US 89 and US 191 have very limited exposure to HAZMAT.
Emergency Response Time	Area-specific, overlapping jurisdictions, long distances between emergency response centers, and long notification times pose the problem, geographical areas of focus are near the Montana/Idaho border on Idaho 20, near the Idaho/Wyoming border on US 89, and Interstate 15 near Idaho Falls, Idaho.
Lack of Traveler/Tourist Information	Regional, the traveler needs survey indicated a lack of available traveler and tourist information throughout the region, the information that is available is often incomplete, inaccurate, or too general in nature.
Failure to Yield Right-of-way or Disregard for Traffic Control	Area-specific, traffic control and access control have large impacts on these types of conflicts, US 191 through Bozeman, Montana and the suburban areas outside Idaho Falls, Idaho on Routes 20 and 26 were identified as the geographical areas of focus.
Rear-end Collisions	Area-specific, U.S. 191 through Bozeman, Montana and the suburban areas outside Idaho Falls, Idaho served by routes Idaho 20, and 26.
Animal Encroachment on the Roadway	Area-specific, conflicts were concentrated due to animal numbers and migration patterns, geographic areas of focus areas most of US 191 through Montana and US 89 from Jackson, Wyoming to Livingston, Montana.
Snowmobile Crashes	Area-specific, Yellowstone National Park has been identified as the geographic area of focus; snowmobile incidents and conflicts are concentrated in this area.
Commercial Vehicle Efficiency	Area-specific, geographic areas of focus center in and around the several weigh stations located in or near the GYRITS Corridor.
Traveler Mobility	Regional, solutions should focus on improving operations of the existing transit and paratransit services supplied by various agencies within the Corridor.
Congestion at Yellowstone National Park Entrances	Area-specific, three entrances to Yellowstone National Park including Gardiner, Montana; West Yellowstone, Montana; and Jackson, Wyoming may be the focus.
Congestion at Construction Zones	Area-specific, specific to planned construction projects that will affect travel within the Corridor.
Tourism and Economic Development	Regional, affects the entire Corridor, solutions should focus on long-term applications.

These project goals have been modified to better align with goals and objectives detailed in the Task 5: ITS Vision Working Paper (see Table 2). Note that the individual goals and objectives described below are still dependent on the specific Corridor challenges. After considering the Task 5: ITS Vision Working Paper goals and objectives, a supplementary challenge was added to the list of challenges identified as part of Task 3. This challenge relates to economic development and tourism industry support. These more clearly defined goals and objectives will help to identify and focus the scope and impact of the GYRITS Corridor Regional Architecture.

Architecture Considerations and Concepts

Planned ITS deployment must follow a defined set of guidelines that allow for complete system integration. The set of guidelines used to deploy ITS technologies includes both the functional characteristics of the technologies and the performance standards necessary to make the deployment successful.

More specifically, architecture development is important because it helps to ensure that:

- new infrastructure deployment is compatible with and builds upon existing systems,
- system components are able to communicate with each other without costly reprogramming and reconfiguration,
- systems work effectively across jurisdictional boundaries, and
- system elements are able to work with each other and future infrastructure deployment for energy and cost savings. (1)

There are three primary scales of architecture: (1) model, (2) regional, and (3) project. Each of these is more fully defined below. In addition, Table 3 provides examples of each architecture scale discussed in this report.

Model Architecture. A model ITS architecture is intended to act as exactly that – *a model* – by defining all possible solutions and issues related to ITS technologies. Transportation providers can pick and choose from an array of possible solutions to transportation challenges and learn of related issues and considerations associated with their selection. The model architecture concept provides a macroscopic look at what ITS has to offer.

Table 2. *GYRITS Priority Corridor Project* Goals and Objectives (2)

Improve the safety and security of the Greater Yellowstone Region rural transportation system users.	
Objectives	• Provide sustainable traveler information systems that disseminate credible and accurate "real-time" information. • Provide systems that advise regional residents of slow-moving vehicles, obstructions, and weather conditions. • Provide systems that advise non-residents of alignment and speed conditions, tourist attractions, services, construction, and weather, and offer the opportunity to request assistance. • Coordinate public fleet responses to unsafe conditions (weather, incidents, detour routes) to provide for improved regional movement. • Reduce severity and fatality rates of crashes through improved emergency response times. • Reduce exposure to unsafe situations through motorist aid devices. • Provide improved methods for monitoring commercial vehicles and identifying hazardous materials.
Enhance personal mobility and accessibility to services and enhance convenience and comfort of travelers destined for Yellowstone National Park and Grand Teton National Park.	
Objectives	• Increase public awareness of public transportation alternatives to and within the parks. • Encourage and provide incentives for increased transit utilization. • Improve access to services and tourist areas through expanded information availability. • Coordinate transit services and availability to parks. • Provide parking information to reduce internal park congestion.
Increase operational efficiency and productivity of the transportation system, focusing on system providers.	
Objectives	• Collect, process, and share data between local, state, and federal agencies to increase efficiency and resources utilization. • Provide automated notification of conditions that may impact operations and maintenance of regional roadways to improve resource management and allocation. • Improve communication system capabilities to provide increased coordination of services (e.g., radio, wire-line/wireless).
Enhance economic productivity of individuals, businesses, and organizations.	
Objectives	• Develop projects that meet local needs but provide for national "showcase." • Improve identification of goods, services, and opportunities in regional communities (e.g., en-route information, transportation service information, etc.) • Provide mechanism by which tourism industry and transportation and transit services can work more closely together. • Provide opportunity for commercial vehicles and goods to be moved more efficiently (e.g., pre-clearance systems).
Reduce energy consumption, environmental costs, and negative impacts.	
Objectives	• Improve hazardous material incident response. • Promote and encourage the use of alternative fuels and the use of transit in the parks.

Table 2. *GYRITS Priority Corridor Project* Goals and Objectives (Continued) (2)

Develop and foster long-term partnerships that will result in the deployment of ITS initiatives and traditional solutions that address rural needs of the region.	
Objectives	• Establish formal and informal opportunities to inform public and private sector decision-makers on initiatives for the Greater Yellowstone Rural ITS Priority Corridor project. • Gain support for ITS efforts from key stakeholders. • Facilitate a technical and financial group for the promotion of partnership projects. • Provide for opportunities for public-public and public-private partnerships for operations and maintenance
Ensure compatibility with statewide and national ITS initiatives.	
Objectives	• Coordinate GYRITS Corridor project with statewide efforts. • Provide for technology transfer between state agencies.
Incorporate ITS into the Statewide Transportation Improvement Program planning efforts.	
Objectives	• Provide for the incorporation of advanced technology applications to be considered in the Statewide Transportation Improvement Program (STIP) process.

Table 3. Architecture Scale Relationships

Type	Examples
Model	• National System Architecture • ARTS Strategic Plan and architecture efforts
Regional	• GYRITS Corridor Regional Architecture
Project	• Early Winner Projects • Strategic Plan Projects

Examples of model architectures include the (1) National System Architecture and (2) Advanced Rural Transportation Systems (ARTS) Strategic Plan and architecture efforts. Each is described more fully below.

National System Architecture. The NSA helps to ensure coordinated ITS deployment by providing guidance for developing regional architectures (discussed later in this section) and national standards. The NSA is essentially a functional outline for the evolutionary deployment of ITS technologies. The NSA is comprised of several components including user services, technologies, market packages, and market package bundles which are described below and in Figure 1.

- User Services: describe what functionality should be provided to make the ITS solution successful (user services have recently been dropped from the formal NSA development process).
- Technologies: the simplest component of an ITS system.
- Market Packages: groups of technologies that have common functionality.
- Market Package Bundles: broad groups of market packages organized according to their common functionality. Seven market package bundles have been developed to help focus the needs of transportation users and providers for application of the National System Architecture. These include: (1) ITS Planning, (2) Advanced Traffic Management, (3) Advanced Traveler Information Systems, (4) Transit Management Systems, (5) Commercial Vehicle Operations, (6) Advanced Vehicles, and (7) Emergency Vehicles.

Use of these NSA components allows consistent and compatible systems to be implemented in a manner that will allow eventual integration on local, regional, and national scales.

Advanced Rural Transportation Systems (ARTS) Strategic Plan and Architecture Efforts. Nationally, few "rural" ITS projects have utilized the NSA as a guide. Application of the NSA is complicated and somewhat confusing in the rural environment. Market packages and user services oriented toward urban problems may not apply. Communications technologies may be restricted to only a few options in rural areas, due to cost and geographic challenges. For these reasons, a *rural* ITS architecture is currently being developed.

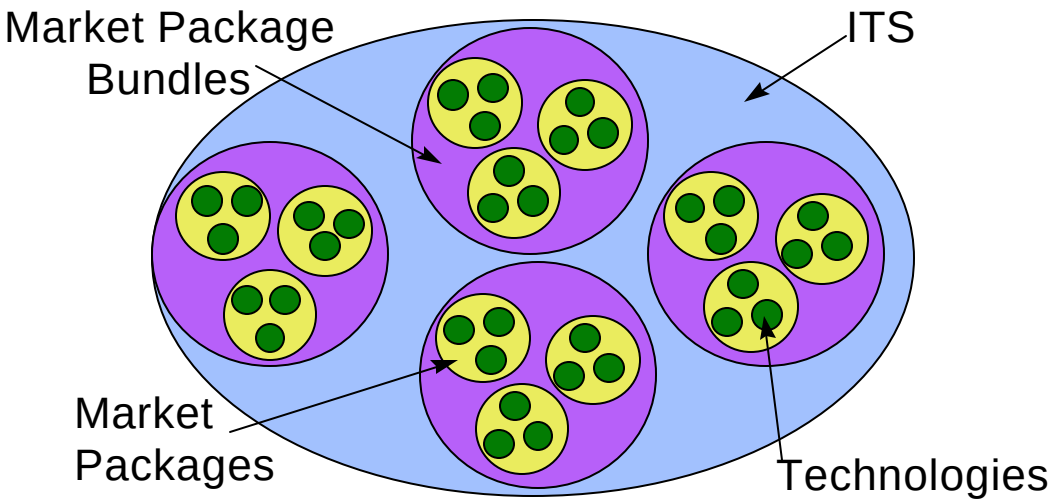

Figure 1. National System Architecture Model

The ITS America Committee on Advanced Rural Transportation Systems (ARTS) sanctioned a subcommittee to define the "building blocks" of a rural architecture, ensuring compatibility with the National System Architecture (NSA). While the ARTS Architecture efforts are still in the developing stages, several aspects of this model architecture have been determined through the ARTS Strategic Plan.

Like the NSA's market package bundles, the ARTS Strategic Plan includes Critical Program Areas (CPAs) that focus on the specific needs of rural transportation users and providers. The CPAs act as groupings for rural market packages, though these rural market packages have yet to be developed. The ARTS Strategic Plan defined seven CPAs:

- Traveler Safety and Security: addresses the need for improving driver ability to operate a vehicle in a safe and responsible way and for improving driver notification of potentially hazardous driving conditions (i.e., poor road conditions, reduced visibility, etc.).

- Emergency Services: focuses on providing improved response when an incident occurs, including reduced emergency notification time, as well as providing additional crash details to enable improved response and care.
- Tourism and Travel Information Services: provides travel information and mobility services to travelers unfamiliar with the rural area and at tourist destinations.
- Public Traveler Services/Public Mobility Services: improves accessibility and reduces isolation for travelers using/relying on public transportation.
- Infrastructure Operations and Maintenance: addresses efficient and effective maintenance and operation of rural roadways and signals.
- Fleet Operations and Maintenance: provides for efficient scheduling, routing, locating, and maintaining of rural fleets.
- Commercial Vehicle Operations: addresses regulation, management, and logistics of commercial fleets and agricultural equipment to meet the needs of rural commercial operators. (3)

Figure 2 illustrates the relationship of technologies, *rural* market packages, and CPAs related to rural ITS. "Orphaned technologies" are those that are so new that they do not fit completely into a currently defined market package. Note the overlap of technologies, rural market packages, orphaned technologies, and the critical program areas found within the ARTS Strategic Plan.

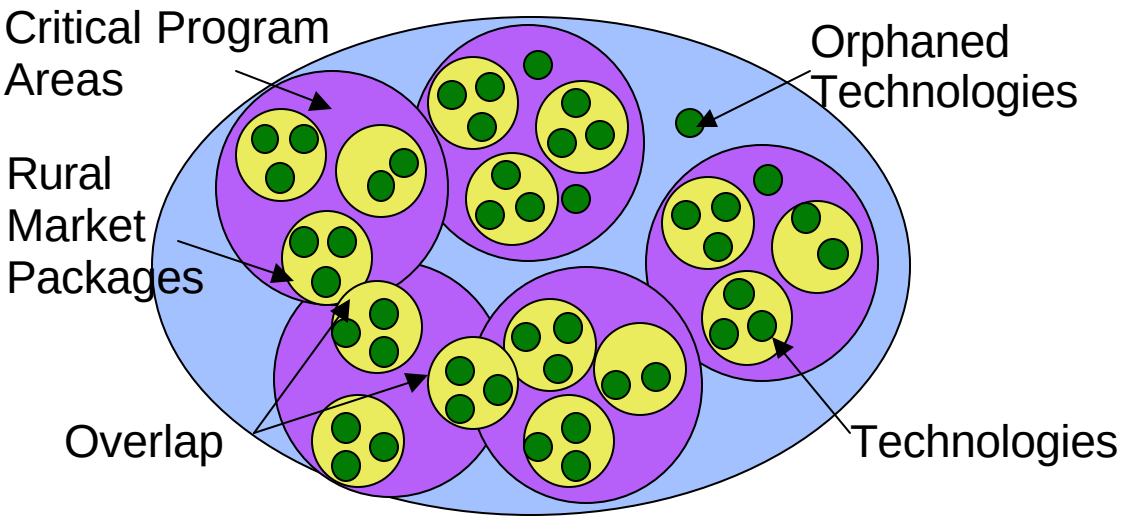

Figure 2. Rural Architecture

Regional Architecture. A regional architecture relies on a model architecture to organize and define the functionality of various technologies and groupings of technologies. However, a regional architecture narrows the set of solutions based on specific challenges and regional goals. The result is a set of technologies that addresses specific *regional* challenges but is compatible with the National System Architecture.

Several considerations are important when developing a regional architecture. The primary step is to define what the system is to provide and to identify potential technologies. This involves analyzing user services and market packages with specific regional challenges in mind. To fully accomplish this process for the rural environment, a number of things must occur:

- a suitable model architecture must be determined,
- rural market packages must be defined, and
- rural market packages must be grouped.

The GYRITS Corridor Regional Architecture will serve as an example of a rural regional architecture.

GYRITS Corridor Regional Architecture. Due to the evolutionary and dynamic nature of model architectures such as the NSA and ARTS architecture efforts, researchers will use a hybrid of the two models to develop the GYRITS Corridor Regional Architecture. Because rural market packages have not yet been defined, researchers will use applicable NSA market packages directly and will modify some of the NSA market package definitions and titles to better reflect rural issues and priorities. The GYRITS Corridor Regional Architecture will comprise existing and redefined NSA market packages reorganized under the ARTS Program CPAs. The result will be a "ruralized" regional architecture. The development of the GYRITS Corridor Regional Architecture will serve as a first attempt at defining a rural architecture that is fully compatible with the NSA - one goal of the ARTS Strategic Plan. NSA compatibility will be ensured because only the scope of the market packages will be slightly modified to match the needs and limitations of the rural environment.

Project Architecture. A project architecture describes the functional and operational relationships of an ITS project, the technologies contained within the system(s), and the relationship to the larger regional architecture. The GYRITS Corridor Regional Architecture will contain several systems, which will have their own communications requirements, technologies, and functions.

Project Intent and Methodology

The intent of this portion of the *Greater Yellowstone Rural ITS Priority Corridor Project* is to support regional architecture development for the GYRITS Corridor by identifying and supplying necessary informational elements and ensuring compatibility with the National System Architecture. (This report addresses three tasks in the larger *GYRITS Priority Corridor Project*: (1) identify and screen market packages (Task 6), (2) develop an ITS concepts report (Task 7), and (3) identify desired functional capabilities (Task 8)). More specifically, this report aims to:

- identify and describe the functionality that should be provided to make ITS solutions successful in the GYRITS Corridor;
- identify market packages and groupings that are best suited for meeting the transportation challenges in the GYRITS Corridor, and hence, have the highest potential for success; and
- investigate various communication technologies appropriate for the GYRITS Corridor; the availability and function of the communications links may drive the function of the systems to be deployed within the region.

Accomplishment of these activities will facilitate future implementation and integration of ITS technologies in the GYRITS Corridor.

The GYRITS Corridor Regional Architecture development process consisted of five distinct steps. In general, the process considered GYRITS Corridor specific challenges, related these to the larger NSA model architecture, adjusted the NSA model architecture to better reflect rural conditions, then used the adjusted model architecture to once again focus on Corridor specific challenges. In accomplishing these steps, matrices were used to map the various relationships among architecture elements. The five-step process is described below and in Figure 3 (Figure 3

is repeated throughout the report to better lead the reader through the various stages of regional architecture development).

It should be noted here that the methodology behind applying the concepts in the NSA has evolved significantly in the recent past. User services have been dropped from the formal NSA process in favor of market packages. While this may add some efficiency to the process, user services help to identify what must be provided to make the ITS solution successful. Therefore, the GYRITS Corridor Regional Architecture development process did include user services to ensure the Corridor challenges, goals, and objectives are met.

Step 1: Relating Corridor Challenges to User Services

The first step in the GYRITS Corridor Regional Architecture development process was to adequately define the needed services or functionality to successfully address each transportation challenge. For example, if a transportation challenge relates to insufficient traveler or tourist information, an appropriate user service may be to provide the traveler or tourist with pre-trip travel information.

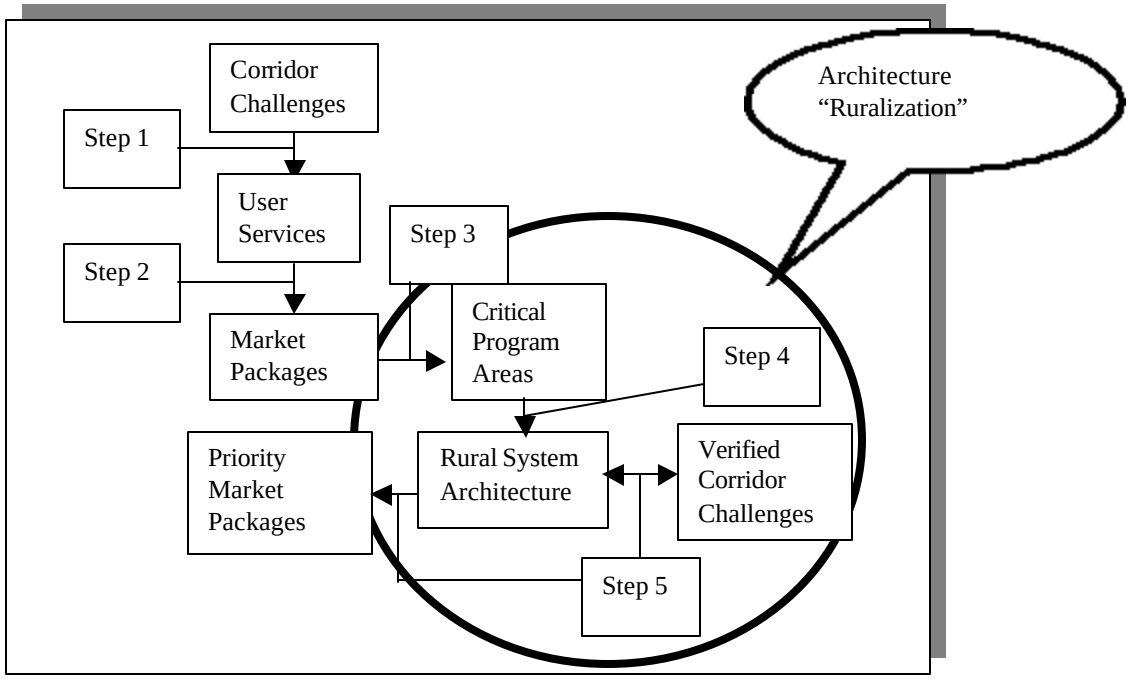

Figure 3. Architecture Development Process

This user service mapping process was repeated for each of the Corridor challenges identified in previous tasks through the use of a matrix. These selected user services define what must be done to address each Corridor challenge.

Step 2: Relating User Services to Market Packages

The second step in the GYRITS Corridor Regional Architecture development process related market packages comprised of individual technologies to the user services selected in Step 1. The market packages and the corresponding technologies were mapped to the selected user services on the basis of their ability to address the underlying transportation challenge.

Step 3: Relating Market Packages to Critical Program Areas

Step 3 deviated from the traditional application of the NSA, allowing for the "ruralization" of the NSA. For the GYRITS Corridor Regional Architecture development, the NSA and the developing ARTS efforts were related and combined. Market packages were mapped to CPAs. This step essentially re-organized the NSA market package bundles into the CPAs.

Step 4: Relating Critical Program Areas to Rural Model Architecture

In Step 4, the critical program areas were combined to create a rural model architecture. This rural model architecture will serve as the basis for developing a regional architecture for the GYRITS Corridor.

Step 5: Verifying Rural Model Architecture

As a process "check," the rural model architecture was related back to the Corridor-specific challenges, goals and objectives to ensure that the architecture will provide the necessary framework to address the transportation challenges of the Corridor. Also, as part of this step, priority rural market packages were selected that will help to define the GYRITS Corridor Regional Architecture.

For this effort, the GYRITS Corridor Regional Architecture was developed and defined to the market package level, with preliminary projects detailing technologies within the market

packages. The more specific equipment package definitions and descriptions are contained within the National System Architecture documents and hence, are not repeated in this report. Instead the NSA documents will be used directly to support the implementation of the GYRITS Corridor Regional Architecture as projects are identified. While this report does not explicitly define the regional architecture, it does identify the necessary elements to define and develop the GYRITS Corridor Regional Architecture.

Report Contents

Following this introductory information, this report describes:

- the definition and selection of user services specific to the GYRITS Corridor;
- the definition and prioritization of market packages for the GYRITS Corridor which involved (1) selecting or redefining the NSA market packages, and (2) prioritizing the market packages on the basis of rural feasibility and their ability to meet the GYRITS Corridor challenges, and project goals and objectives;
- implementation considerations, including a review of viable communication technologies; and
- the next steps as part of the larger *Greater Yellowstone Rural ITS Priority Corridor Project*, which include defining the GYRITS Corridor Regional Architecture.

DEFINITION AND SELECTION OF USER SERVICES

This section describes the first step in the GYRITS Corridor Regional Architecture development process - to relate Corridor-specific challenges and project goals and objectives to user services (see Figure 3).

Defining User Services

Recall that user services describe what functionality should be provided to make an ITS solution successful. Users may include departments of transportation, commuters, recreational travelers, recreational businesses, advertisers, agricultural users, transit operators and passengers, emergency service providers, non-motorized vehicle operators, and commercial vehicle operators. User service descriptions are composed of two components:

- a "label" that identifies the user service and gives an indication of its nature; and
- a "description" that explains and confirms the user service to the user and to the developer. (3)

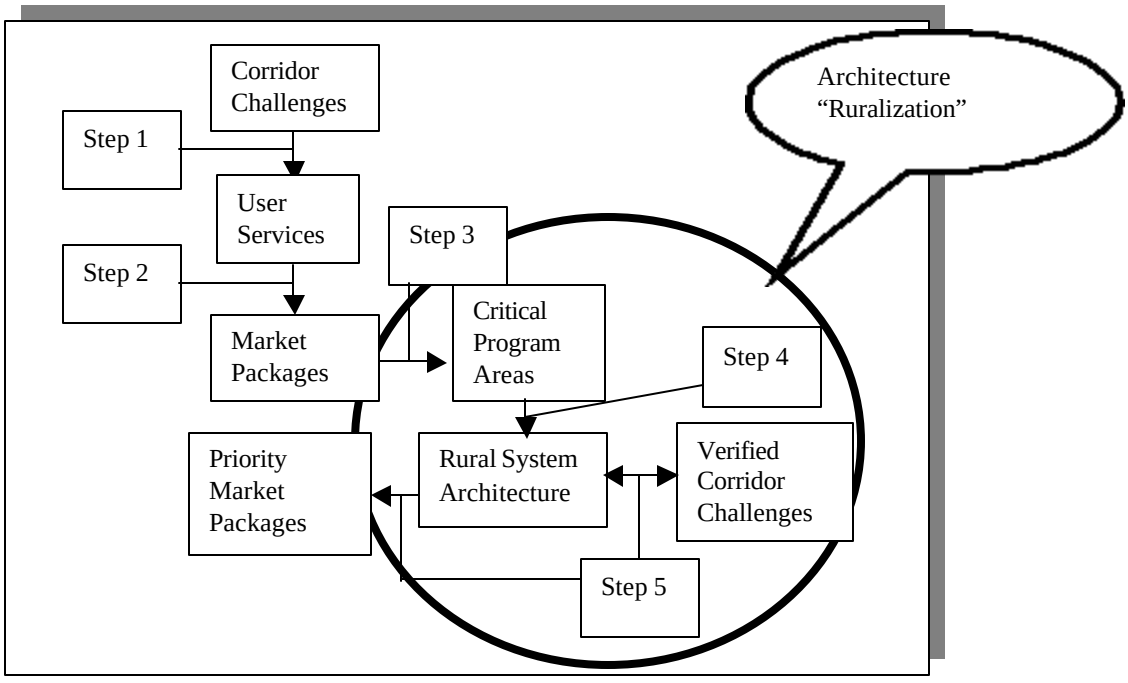

Figure 3. Architecture Development Process (Repeated)

The NSA formerly included 30 user services organized into seven bundles (recall that the NSA abandoned the use of user services in favor of market packages). The bundles are logical groupings of the user services that incorporate common functionality or utilization of common technologies.

In order to capture all needs and services particular to rural environments, one additional bundle comprised of three user services was developed for rural concerns. These "rural-specific" user services may likely influence the selection of GYRITS Corridor market packages that are later defined.

Table 4 provides a list of the 33 potential user services, grouped by bundle, with a brief description of their functions. Researchers for this effort focused the functional descriptions of the NSA user services on rural functionality rather than urban functionality. For example, no mention is made of recurring traffic congestion mitigation or other largely urban-specific challenges. Some of the user services may not be directly applicable to rural activities, but are listed below for completeness.

Relating User Services to Corridor Challenges

Association of the 33 user services to the GYRITS Corridor transportation challenges identified through an accident analysis, a traveler needs survey, and stakeholder meetings was accomplished through a standard mapping exercise. The selection of the various user services was largely intuitive, given the nature of the Corridor challenge and the functionality of each user service.

Table 5 summarizes the user services deemed applicable to the GYRITS Corridor. Note that some user services apply to several Corridor challenges while some user services have no application in this project.

Table 4. Potential User Services

BUNDLE	USER SERVICE	RURAL-TAILORED FUNCTIONAL DESCRIPTION
Travel and Transportation Management	En-Route Driver Information	provides dynamic driver advisories in the vehicle and along the roadway for convenience and safety during travel
	Route Guidance	provides travelers with simple instructions on how to best reach their destinations
	Traveler Services Information	provides information on traveler services such as food, phone, gas, lodging, and campgrounds
	Traffic Control	manages the movement of traffic on streets and highways
	Incident Management	helps public and private organizations quickly identify incidents and implement a response to minimize their effects on traffic
	Emissions Testing and Mitigation	provides information for monitoring air quality and developing air quality improvement strategies
	Highway - Rail Intersection	helps address safety concerns at highway-rail intersections
Travel Demand Management	Pre-Trip Travel Information	provides information for selecting the best transportation mode, departure time, and route
	Ride Matching and Reservation	makes ridesharing easier and more convenient
	Demand Management and Operations	supports policies and regulations designed to mitigate the environmental and social impacts of traffic and parking congestion
Public Transportation Operations	Public Transportation Management	automates operations, planning, and management functions of public transit systems
	En-Route Transit Information	provides information to travelers using public transportation after they begin their trips
	Personalized Public Transit	flexibly routes transit vehicles to offer more convenient service to customers
	Public Travel Security	creates a secure environment for public transportation patrons and operators
Electronic Payment Services	Electronic Payment Services	allows travelers to pay electronically for transportation services, such as public transit or parking
Commercial Vehicle Operations	Commercial Vehicle Electronic Clearance	facilitates domestic and international clearance at borders and ports of entry, minimizing stops
	Automated Roadside Safety Inspection	facilitates roadside inspections

Table 4. Potential User Services (Continued)

BUNDLE	USER SERVICE	RURAL-TAILORED FUNCTIONAL DESCRIPTION
Commercial Vehicle Operations (Continued)	On-Board Safety Monitoring	senses the safety status of a commercial vehicle, cargo, and driver
	Commercial Vehicle Administrative Processes	provides electronic purchasing of credentials and automated mileage and fuel reporting and auditing
	Hazardous Material Incident Response	provides immediate description of hazardous materials to emergency responders
	Commercial Fleet Management	provides communications between drivers, dispatchers, and inter-modal transportation providers
Emergency Management	Emergency Notification and Personal Security	provides immediate notification of an incident and an immediate request for assistance
	Emergency Vehicle Management	reduces the time it takes emergency vehicles to respond to an incident
Advanced Vehicle Control and Safety Systems	Longitudinal Collision Avoidance	helps prevent head-on, rear-end, or backing collisions between vehicles, or between vehicles and other objects or pedestrians
	Lateral Collision Avoidance	helps prevent collisions when vehicles leave their lane of travel
	Intersection Collision Avoidance	helps prevent collisions at intersections
	Vision Enhancement for Crash Avoidance	helps improve the driver's ability to see the roadway and objects that are on or along the roadway
	Safety Readiness	provides warnings about the condition of the driver, the vehicle, and the roadway
	Pre-Crash Restraint Deployment	anticipates an imminent collision and activate passenger safety systems before the collision occurs, or much earlier in the crash event than is currently feasible
	Automated Highway Systems	provides a fully automated, hands-off operating environment
Advanced Rural Transportation Systems (ARTS)	Animal-vehicle Collisions Countermeasures	addresses collisions of vehicles and animals through application of technology
	Effective Road Maintenance and Management	addresses efficient and effective maintenance and operation of rural roadways and signals
	Seasonal Congestion Management	addresses increased demand during seasonal activities, includes aspects of traffic control, road management, and commercial fleet operations

Table 5. GYRITS Corridor User Services

Corridor Challenges / User Service	Inclement Weather	Unsafe Speed	Commercial Vehicle Safety	Hazardous Materials Response	Slow Emergency Response Times	Lack of Traveler/ Tourist Information	Failure to Yield or Disregard for Traffic Control	Rear-end Collisions	Animal Encroachments on the Roadway	Snowmobile Crashes	Commercial Vehicle Efficiency and Infrastructure Damage	Traveler Mobility	Congestion at YNP Entrances	Congestion at Construction Zones	Tourism/Economic Development
Travel and Transportation Management															
En-Route Driver Information	√												√	√	
Route Guidance	√											√	√	√	
Traveler Services Information	√					√							√		
Traffic Control															
Incident Management	√			√	√										
Emissions Testing/Mitigation															
Highway - Rail Intersection															
Travel Demand Management															
Pre-Trip Travel Information	√												√		
Ride Matching and Reservation						√						√			
Demand Management and Operations													√	√	
Public Transportation Operations															
Public Transportation Management												√	√		
En-Route Transit Information												√	√		
Personalized Public Transit												√			
Public Travel Security															
Electronic Payment Services															
Electronic Payment Services													√		√
Commercial Vehicle Operations															
Commercial Vehicle Electronic Clearance			√								√				

Table 5. GYRITS Corridor User Services (Continued)

Corridor Challenges / User Service	Inclement Weather	Unsafe Speed	Commercial Vehicle Safety	Hazardous Materials Response	Slow Emergency Response Times	Lack of Traveler/ Tourist Information	Failure to Yield or Disregard for Traffic Control	Rear-end Collisions	Animal Encroachments on the Roadway	Snowmobile Crashes	Commercial Vehicle Efficiency and Infrastructure Damage	Traveler Mobility	Congestion at YNP Entrances	Congestion at Construction Zones	Tourism/Economic Development
Commercial Vehicle Operations (Continued)															
Automated Roadside Safety Inspection			√												
On-Board Safety Monitoring			√												
Commercial Vehicle Administrative Processes											√				
Hazardous Material Incident Response				√											
Commercial Fleet Management											√				
Emergency Management															
Emergency Notification and Personal Security	√				√										
Emergency Vehicle Management	√				√										
Advanced Vehicle Control and Safety Systems															
Longitudinal Collision Avoidance	√							√	√	√					
Lateral Collision Avoidance	√									√					
Intersection Collision Avoidance							√			√					
Vision Enhancement for Crash Avoidance	√									√					
Safety Readiness	√	√													
Pre-Crash Restraint Deployment							√								
Automated Highway Systems		√													
Advanced Rural Transportation Systems (ARTS)															
Animal-vehicle Collisions Countermeasures									√						
Effective Road Maintenance and Management	√													√	
Seasonal Congestion Management													√	√	

DEFINITION AND SELECTION OF MARKET PACKAGES

Recall that market packages are defined as groups of technologies that have been bundled together to provide a measurable service or benefit to the user of the system. User services and market packages are closely related. User services are the "what" and market packages are the "how" in addressing transportation-related problems and needs.

In general, market packages:

- describe how to provide one or more ITS user services;
- offer a physical or tangible means of satisfying user requirements;
- are concrete items rather than abstract functions, that can or will be purchasable in the marketplace;
- are technology dependent, but not technology specific;
- are the building blocks of a regional architecture;
- allow incremental deployment options that may apply to different scenarios and time-frames, and assist in the selection of technological solutions;
- may be used to describe and characterize legacy systems, define future architecture, and indicate suitable evolutionary deployment paths; and
- may be used to illustrate the potential ITS solutions available in the marketplace today and in the future to non-technical users. (1)

Each market package addresses the specific service requirements of traffic managers, transit operators, travelers, and ITS stakeholders. In all, 53 market packages have been identified as part of the NSA. However, it is likely that additional market packages will be identified and defined as technological development continues, new products and services emerge, and more practical experience is gained in applying the NSA.

This section describes both the second and third steps in the GYRITS Corridor Regional Architecture development process (see Figure 3). Specifically, this step identified the relationship between the proposed GYRITS user services and the individual market packages allowing preliminary identification of technologies that will help address the challenges of the

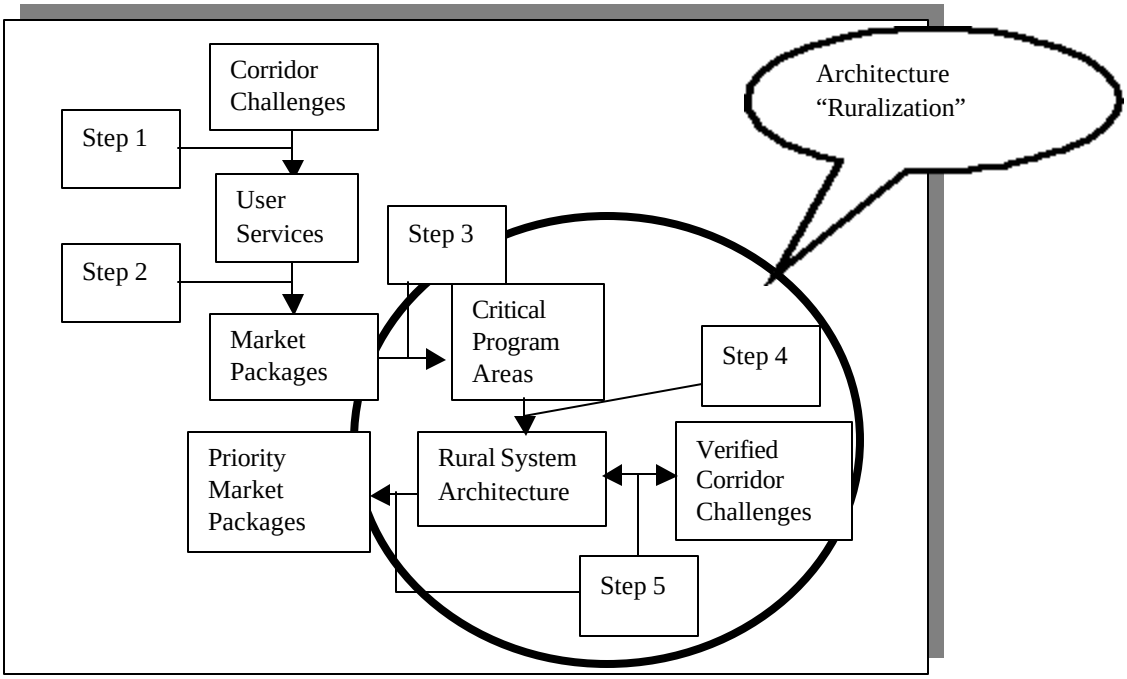

Figure 3. Architecture Development Process (Repeated)

Corridor (i.e., Step 2). In addition, the NSA market packages were related to the critical program areas defined by the Advanced Rural Transportation Systems Architecture Subcommittee (i.e., Step 3.

Relating User Services to Market Packages

Using a mapping matrix, the correlation between the user services and market packages is illustrated. Through the mapping exercise, researchers were able to intuitively determine the market packages that would best address the user services. While quite simple, this process helps to ensure that each user service is addressed through a market package. If none of the defined market packages were found to adequately address a user service, it was necessary to consider traditional countermeasures or define/create a new market package. Table 6 summarizes the NSA market packages directly applicable to the GYRITS Corridor determined from the mapping exercise.

Table 6. Summary of Applicable NSA Market Packages

TRAFFIC MANAGEMENT	EMERGENCY MANAGEMENT
• Facility Use/Parking Fee Management • Incident Management System • Network Surveillance • Probe Surveillance • Surface Street Control • Traffic Information Dissemination • Virtual Traffic Management Center	• Emergency Response • Emergency Routing • Mayday Support
TRANSIT MANAGEMENT	COMMERCIAL VEHICLES
• Demand Response Transit Operations • Multimodal Coordination • Transit Fixed-Route Operations • Transit Maintenance • Transit Passenger and Fare Management • Transit Vehicle Tracking	• CVO Fleet Maintenance • Electronic Clearance • Electronic Clearance Enrollment/Credentials • Fleet Administration • Freight Administration • HAZMAT Management • On-board CVO Safety • Roadside CVO Safety • Weigh-in-motion
TRAVELER INFORMATION SYSTEMS	ADVANCED VEHICLES
• Autonomous Route Guidance • Broadcast Traveler Information • Dynamic Ridesharing • Dynamic Route Guidance • Integrated Transportation Management/Route Guidance • Interactive Traveler Information • In-Vehicle Signing • ISP-based Route Guidance • Yellow Pages and Reservation	• Advanced Vehicle Lateral Control • Advanced Vehicle Longitudinal Control • Automated Highway System • Driver Safety Monitoring • Driver Visibility Improvement • Intersection Collision Avoidance • Intersection Safety Warning • Lateral Safety Warning • Longitudinal Safety Warning • Pre-Crash Restraint Deployment • Traction Control • Vehicle Safety Monitoring

Relating Market Packages to Critical Program Areas

The NSA has been developed through an evolutionary process, initially for application in urbanized areas. During this process, several market packages were defined and accepted which have little or no applicability in the rural environment. It has been previously stated that market packages are technology dependent, but not technology specific. Current NSA market packages may be dependent on technologies that are not practical or useful in the rural environment.

The GYRITS Corridor tests the NSA's ability to accommodate rural needs and reveals the associated architecture limitations. For example, the absence of wireless and/or wire-line communications can cause serious communications and reliability challenges. Hence, this effort required the modification of some market package definitions, as well as the creation of some new market packages. To aid in reorganizing the architecture and the "creation" of new market packages, the NSA market packages were mapped to the ARTS Critical Program Areas (see Table 7). This reorganization illustrated the overlap of market packages within the CPAs. In many instances, one market package appears in several CPAs. The combined scope of the overlapping CPAs helped to define the new market packages.

Rural Market Package Definitions

The rural market packages are chosen based on their ability to provide a solution to previously identified Corridor challenges. These solutions may be categorized for short, medium, or long-term implementation. Once identified for implementation, the required subsystems, equipment packages, and interface requirements for the market packages are easily identified through the use of the NSA documents.

The NSA market packages deemed appropriate, either directly or with slight modification, for the GYRITS Corridor are defined below, categorized by Critical Program Area. Following these definitions, new market packages created to meet specific rural challenges are defined. These two sets of market packages will form the basis for the GYRITS Corridor Regional Architecture.

Table 7. Relating NSA Market Packages to Critical Program Areas

Critical Program Areas / Market Packages	Traveler Safety and Security	Emergency Services	Tourism and Travel Information Services	Public Traveler Services/Public Mobility Services	Commercial Vehicle Operations	Infrastructure Operations and Maintenance	Fleet Operations and Maintenance
Advanced Vehicle Lateral Control	√						
Advanced Vehicle Longitudinal Control	√						
Automated Highway System	√						
Autonomous Route Guidance	√						
Broadcast Traveler Information			√			√	
CVO Fleet Maintenance					√		√
Demand Response Transit Operations				√			√
Driver Safety Monitoring	√				√		√
Driver Visibility Improvement	√				√		
Dynamic Ridesharing			√	√			
Dynamic Route Guidance	√						
Electronic Clearance					√	√	√
Electronic Clearance Enrollment	√				√		√
Emergency Response	√	√					
Emergency Routing		√					
Facility Use/ Parking Fee Management			√	√			
Fleet Administration					√		√
Freight Administration					√		√
HAZMAT Management					√	√	√
Incident Management System	√					√	
Interactive Traveler Information			√				
Intersection Collision Avoidance	√						
Intersection Safety Warning	√						

Table 7. Relating NSA Market Packages to Critical Program Areas (Continued)

Critical Program Areas / Market Packages	Traveler Safety and Security	Emergency Services	Tourism and Travel Information Services	Public Traveler Services/Public Mobility Services	Commercial Vehicle Operations	Infrastructure Operations and Maintenance	Fleet Operations and Maintenance
In-Vehicle Signing			√				
ISP-based Route Guidance	√						
Lateral Safety Warning	√				√		
Longitudinal Safety Warning	√				√		
Mayday Support	√	√					
Mobile Traffic Management/Enforcement	√					√	
Multimodal Coordination				√			√
Network Surveillance	√					√	
On-board CVO Safety					√		√
Pre-crash Restraint Deployment	√						
Probe Surveillance						√	
Roadside CVO Safety					√	√	√
Surface Street Control						√	
Traction Control	√						
Traffic Information Dissemination	√		√			√	
Transit Fixed-route Operations				√			√
Transit Maintenance							√
Transit Passenger and Fare Management				√			√
Transit Vehicle Tracking				√			√
Vehicle Safety Monitoring	√				√		√
Virtual Traffic Management Center		√		√		√	
Weigh-in-motion					√	√	
Yellow Pages and Reservation			√				

Traveler Safety and Security

Several of the market packages selected for the GYRITS Corridor relate to traveler safety and security. These include the following:

- Advanced Vehicle Lateral Control
- Advanced Vehicle Longitudinal Control
- Automated Highway Systems
- Autonomous Route Guidance
- Driver Safety Monitoring
- Driver Visibility Improvement
- Dynamic Route Guidance
- Electronic Clearance Enrollment
- Emergency Response
- Incident Management Systems
- Intersection Collision Avoidance
- Intersection Safety Warning
- ISP-based Route Guidance
- Lateral Safety Warning
- Longitudinal Safety Warning
- Mayday Support
- Mobile Traffic Management/Enforcement
- Network Surveillance
- Pre-Crash Restraint Deployment
- Traction Control
- Traffic Information Dissemination
- Vehicle Safety Monitoring

Advanced Vehicle Lateral Control. Advanced vehicle lateral control automates the steering control on board the vehicle. It utilizes safety sensors and collision sensors combined with vehicle dynamics processing to control the steering. It requires on-board sensors to measure lane position and lateral deviations and a processor to control the vehicle steering.

Advanced Vehicle Longitudinal Control. Advanced vehicle longitudinal control provides the functionality to automate vehicle speed and headway control. Utilizing radar or infrared ranging technologies to detect the distance to the vehicle in front, a microprocessor-based control system will assess vehicle speed, process sensor inputs, and determine appropriate control actions, such as automatic braking, acceleration, or speed maintenance through the application of automated vehicle control techniques.

This market package is sometimes referred to as "intelligent cruise control" because it extends the functionality of currently available cruise control systems by determining appropriate between vehicle headways. Intelligent cruise control incorporates forward-looking sensors to enhance the cruise control service so that the vehicle is continuously kept at a safe following distance from the vehicle in front. This distance would vary with vehicle speed, and the driver may be able to adjust the distance to better fit his or her comfort level. Automatic power train control actuation is used to increase and decrease speed. When needed, some gentle actuation of the brakes may occur.

Automated Highway Systems. These technologies provide the capability to automate some or all of the driving functions through the incorporation of one or a combination of the following market packages:

- longitudinal control,
- driver vision enhancement,
- private vehicle safety, and
- on-board safety.

Autonomous Route Guidance. Autonomous route guidance relies on in-vehicle sensors to determine vehicle location, a computational map database, and an interactive driver interface to enable route planning and detailed route guidance. No communication with the infrastructure is assumed or required. Identical capabilities are available to the traveler outside the vehicle by integrating similar equipment into portable devices. Technological limitations include the receiving capabilities of the location technology.

Driver Safety Monitoring. Driver safety monitoring will determine the driver's condition and warn the driver of potential dangers. On-board sensors will determine the driver's condition and performance, determine on-board safety data, and display information.

Driver Visibility Improvement. Driver visibility improvement includes technologies that enhance driver vision on board the vehicle. The market package will use sensor technologies such as infrared and ultraviolet vision systems and heads up displays to provide the driver with an enhanced view of the road ahead, as well as potential hazards.

Dynamic Route Guidance. Dynamic route guidance offers the user advanced route planning and guidance capabilities, which are responsive to current road, weather, and traffic conditions. The package combines the autonomous route guidance equipment with a digital receiver capable of receiving real-time traffic, transit, and road condition information that is used to provide route guidance.

Electronic Clearance Enrollment/Electronic Credentials. Electronic clearance enrollment/electronic credentials provides automated license application and purchase, reporting of license and credential status, and pre-clearance opportunities at roadside inspection stations. Credentials such as licenses and inspection certificates can be electronically purchased and stored on the vehicle. This allows the vehicle operator to remotely obtain credentials in bulk by logging on to a computer/communication-based credential acquisition and monitoring system.

A typical implementation would utilize automatic vehicle identification (AVI) transponders with two-way read/write capability and a high-speed vehicle-to-roadside communication link. Roadside infrastructure may consist of transceivers linked to a wire-line communication network that interfaces with the relevant regulatory agency. Roadside inspection stations would also be equipped with weigh-in-motion sensors (described below) and wire-line links back to a central database.

Emergency Response. Emergency response automates emergency vehicle notification upon verification of the location and nature of an incident. This market package uses existing and emerging vehicle position locators and sensors for incident detection. Coordination supports emergency notification and coordinated response between agencies. Existing wide area wireless communications would be utilized to coordinate an emergency vehicle with the emergency fleet. An Emergency Management Center would comprise hardware and software for tracking the emergency vehicles. Law enforcement and emergency response agencies are an integral part of this package.

This market package may also include signal preemption, which allows emergency vehicles such as ambulances, fire trucks, and police vehicles to have limited control over traffic signals. Emergency vehicles may override traffic signal sequences, thus reducing response times to incidents.

Incident Management System. Incident management systems help to manage both predicted and unexpected incidents so that the impact on the transportation network and traveler safety is minimized. An important consideration for incident management systems is institutional and regional coordination between traffic management and emergency management centers. Information from diverse sources (e.g., electronic loop detectors, CCTV cameras, motorist call-ins) is collected and correlated to detect and verify incidents, as well as to help formulate an adequate and timely response.

A traffic management center (TMC) may support traffic operations, emergency, and other incident response personnel in developing an appropriate response to an incident. The response may include modifying traffic control strategies and presenting information to affected travelers using the traffic information dissemination technologies, when available. The TMC may also assist field personnel by monitoring incident status as the response unfolds. Coordination with emergency management might be through a computer-aided dispatch (CAD) system or through other communication with emergency field personnel. The coordination can also extend to tow trucks and other field personnel.

Intersection Collision Avoidance. Intersection collision avoidance includes technologies for monitoring intersection condition and generating warnings and control actions. Roadside sensors monitor a vehicle's position and closing rate as it approaches an intersection. A control system then accepts this data and determines the probability of a collision at the intersection. It then generates appropriate warnings and control actions, which are transmitted to the affected vehicles. Short-range vehicle-to-roadside communication techniques will be used to communicate with the vehicles.

Intersection Safety Warning. Intersection safety warning will determine the probability of an intersection collision and provide timely warnings to drivers in response to hazardous conditions. Sensors in the roadway infrastructure are used to assess vehicle locations and speeds near an intersection. Using this information, a warning is determined and communicated to the approaching vehicle using a short-range communications system. This market package may represent an extension to the In-Vehicle Signing market package that may be adapted to support the intersection safety warning application and associated real-time performance requirements.

ISP-based Route Guidance. Information service provider-based route guidance moves the route planning function to the information service provider. This approach can provide better information, enabling better prediction of future traffic and appropriate control strategies. The package includes two-way data communications and optional vehicle databases/ equipment, location determination capability, and display technology to support turn-by-turn route guidance.

Lateral Safety Warning. Lateral safety warning utilizes on-board safety and collision sensors to monitor the areas to the sides of the vehicle and present warnings to the driver about potential hazards.

Longitudinal Safety Warning. Longitudinal safety warning utilizes on-board safety and collision sensors to monitor the areas in front of and behind a vehicle. Warnings are presented to the driver about potential hazards.

Mayday Support. Mayday support allows the user (driver or non-driver) to initiate a request for emergency assistance, either manually or automatically. A user could access this service by installing a simple device in the vehicle or using a cellular telephone in combination with global positioning systems (GPS) or automatic vehicle location (AVL) devices. The request for assistance could be directly routed to emergency services personnel or to a separate control center, depending on organizational arrangements.

A roadside emergency call system may be included, in which motorists in distress use a roadside mounted station to call for assistance. The "call boxes" are typically mounted every half-mile to two miles apart and may use wire-line or wireless communications to connect the call box and emergency personnel. In remote locations, solar cells have been used as a source of power.

Mobile Traffic Management/Enforcement. Mobile traffic management/enforcement increases the effectiveness of regulatory and enforcement activities within the surface street/highway network and enables the implementation of effective traffic management strategies for recurring and non-recurring incidents. The traffic management activities can be used for maintenance activities, special events, animal herds in the roadway, and congestion at access points and points of interest. The enforcement activities may be used for speeding, tailgating, violation of traffic

control, and mountain pass closures. This market package is primarily low-tech but may be semi-automated with operator control using currently available technologies.

Network Surveillance. Network surveillance provides fixed roadside surveillance and/or traffic data gathering using wire-line or wireless communications to transmit the surveillance data. Functions provided include:

- traffic flow monitoring,
- incident identification and verification,
- weather and road condition identification and verification,
- data collection and analysis, and
- dissemination of raw information to users and service providers.

Its use can be completely local, such as loop detection connected with signal control, or it can be regional, such as road weather information system (RWIS) data collection and closed-circuit television (CCTV) cameras that send back data to traffic management centers for regional use. Surveillance capabilities provide traffic engineers with the ability to monitor and manage traffic and maintenance operations along major highways and corridors. Network surveillance capabilities can be further integrated with traveler information networks, including Internet, dedicated TV, and maintenance management center operations.

Pre-crash Restraint Deployment. Pre-crash restraint deployment provides in-vehicle sensors to monitor a vehicle's local environment, determine collision probability, and deploy a pre-crash safety system. It will include on-board sensors to measure lateral and longitudinal gaps. Combined with weather and roadway condition information, it will determine lateral and longitudinal collision probability and will be able to deploy a pre-crash safety system as needed.

Traction Control. Traction control uses sensors on board the vehicle to detect when the tire-to-road surface coefficient of friction is reduced due to water, ice, or road surface condition. The driver is warned of reduced traction; this warning could increase as the severity of the loss of friction increases. The capability of this market package could vary substantially from a simple warning light of possible traction loss (as some vehicles have today) to an indication of the

percent of traction loss. This could be necessary for systems that control the vehicle response to the traction loss.

Traffic Information Dissemination. Traffic information dissemination enables the communication of traffic information to travelers through a variety of potential communication mediums including radio, Internet, and dedicated short-range communication (DSRC). Priority is given to disseminating information related to road conditions, weather conditions, traffic congestion, incidents, and construction delays. Supplementary information such as alternate routes and weather forecasts may also be part of the information package. Regardless of the type of information provided, the messages should be of uniform format, collection, and presentation to ensure reliability, validity, and credibility of the system.

Vehicle Safety Monitoring. Vehicle safety monitoring will diagnose problems with critical components of a vehicle and warn a driver of potential dangers. On-board sensors will determine the vehicle's condition and performance, and determine on-board safety data and display information.

Emergency Services

Emergency Services market packages appropriate for the GRYITS Corridor include the following:

- Emergency Response (previously defined)
- Emergency Routing
- Mayday Support (previously defined)
- Virtual Traffic Management Center

Emergency Routing. Emergency routing assists emergency response personnel in reaching the site of an incident in the most efficient and effective manner. It can also support dynamic routing of emergency vehicles for special priority. Either in-vehicle navigational capabilities or an emergency dispatch center provides the route planning function for the emergency fleet based on real-time traffic conditions and the emergency routes assigned to other responding vehicles.

The emergency vehicle could also be equipped with dedicated short-range communications (DSRC) for local traffic signal preemption.

Virtual Traffic Management Center (TMC). A virtual traffic management center will provide support of other technologies through operational networks. A TMC in a rural environment will operate similarly in scope to its urban counterpart but will be smaller in scale. Hardware requirements will be minimal and could include a virtual network of several desktop PC's connecting several jurisdictions and agencies. Simplicity of data transfer, common needs, and agency roles and responsibilities are key issues to the success of a virtual TMC. The virtual TMC will be the primary means of human interface with the various ITS market packages, and will act as the hub of all information transfers.

Tourism and Travel Information Services

Market packages related to tourism and travel information services for the GYRITS Corridor include the following:

- Broadcast Traveler Information
- Dynamic Ridesharing
- Facility Use/Parking Fee Management
- Interactive Traveler Information
- In-Vehicle Signing
- Traffic Information Dissemination (previously defined)
- Yellow Pages And Reservations

Broadcast Traveler Information. Broadcast traveler information involves the collection, processing, and dissemination of suitable data and information for travelers. The package will typically consist of:

- a data collection network,
- a data fusion facility, and
- an information dissemination network.

By its nature, broadcast traveler information supports several other market packages.

Dynamic Ridesharing. Dynamic ridesharing enhances the Interactive Traveler Information market package by adding infrastructure-based route planning. The investment to the driver or traveler should not increase. If this service is provided by a private information service provider (ISP), service fees may be required to allow for recovery of the ISP investment. In terms of equipment requirements, the Dynamic Ridesharing market package is similar to the Yellow Pages and Reservations market package.

Facility Use/Parking Fee Management. Facility use/parking fee management allows a facility to manage its operations, coordinate with the transportation authorities, and collect fees. Integration with tollgate and AVI will help enable macro-scale management of larger facilities such as national and state parks. Space availability is reported to subscribing travelers which would then direct drivers to the available space. It can also include support for electronic transaction management, enabling the facility operator to charge automatically for the use of the facility. This market package has great potential for seasonally congested attractions including parks, parking facilities and campgrounds.

Interactive Traveler Information. Interactive traveler information provides information tailored to a traveler's request. The user can request and obtain current information regarding traffic conditions, transit services, traveler services, ridesharing/ride matching, parking, and potentially, the availability of campgrounds or other facilities. A range of two-way, wide-area wireless and wire-line communications systems may be used to support the required digital communications between the traveler and the information service provider. The traveler may use a variety of interactive devices to access the information either prior to a trip or while en-route. These devices include phone, kiosk, personal digital assistant (PDA), personal computer, and a variety of in-vehicle devices. Successful deployment of this market package relies on the availability of real-time transportation data and information.

In-vehicle Signing. In-vehicle signing provides an in-vehicle display of locally relevant information including incidents, construction, or adverse roadway conditions. The information may be solicited by the driver as needed or automatically provided to the driver audibly and/or visually. The system may be: (1) incorporated into other in-dash devices such as the radio, (2)

incorporated into an on-dash device such as a radar detector, or (3) stand-alone. The system requires the installation of roadside and in-vehicle communication hardware. Roadside hardware is typically in the form of roadside transceivers or beacons with short-range wireless communication capabilities to pass information to equipped vehicles. The beacons can be independent, carrying only a very local message about the immediate driving context such as advisory speed limit on approach to a sharp bend. The beacons can also be networked by wire-line system back to a control center, enabling more flexible messaging.

Low power advanced highway advisory radio is an example where the car radio is the communication device inside the vehicle. In this case, the beacon broadcasts its message on a commercial radio frequency but at low power in order to avoid interference with commercial radio operations.

Yellow Pages and Reservations. Yellow Pages and reservations enhance the Interactive Traveler Information market package by adding information. The same basic equipment is included; service or advertising fees may encourage information service providers to offer the service. This market package allows for different information access methods including pre-trip, en-route, and in-vehicle using different communication media.

Public Traveler Services/Public Mobility Services

Public traveler services/public mobility services market packages appropriate for the GRYITS Corridor include the following:

- Demand Responsive Transit Operations
- Dynamic Ridesharing (previously defined)
- Facility Use/Parking Fee Management (previously defined)
- Multimodal Coordination
- Transit Fixed-Route Operations
- Transit Passenger And Fare Management
- Transit Vehicle Tracking

- Virtual Traffic Management Center (previously defined)

Demand Responsive Transit Operations. Demand responsive transit operations perform automatic driver assignment and monitoring as well as vehicle routing and scheduling. This market package uses an AVL database to monitor the current status of the transit fleet and allocate fleet resources to service incoming requests for transit service. The necessary data processing and information display is provided to assist the transit operator in making optimal use of the transit fleet. Traveler equipment is also included within this market package to enable traveler requests for flexible route transit and paratransit service. The traveler can make a direct request to a specific paratransit service, or a third party service provider can determine a paratransit service that is a viable means of satisfying the travelers' request. Wire-line communications are used to make a reservation for the traveler.

This market package has the potential to include an automated dispatching function. Once demand reaches a certain point or a specific request is made, the transit vehicle is automatically dispatched.

Multimodal Coordination. Multimodal coordination establishes two-way communications between multiple transit and traffic agencies to improve service coordination. Coordination between transit agencies can increase traveler convenience at transfer points and also improve operating efficiency. Coordination between traffic and transit management is intended to improve on-time performance of the transit system providing that the overall performance of the traffic network is not degraded. Limited local coordination between a transit vehicle and an individual intersection for signal priority is also provided by this market package.

Transit Fixed-route Operations. Transit fixed-route operations performs automatic driver assignment and monitoring as well as vehicle routing and scheduling for fixed-route services. This market package uses an automatic vehicle location (AVL) database to determine current schedule performance. This data is then processes, transmitted to either an information service provider for dissemination to the public or directly to the public. The data may be integrated with data from other transportation modes to provide the public with integrated and personalized dynamic schedules.

Transit Passenger and Fare Management. Transit passenger and fare management allows transit operators to maximize operational efficiency and transit demand prediction. Passenger loads on individual vehicles are determined through the use of doorway sensors. Both the vehicle operator and central operation staff can access passenger volume information in real-time. This information can be used to review deployment of the vehicle fleet in real-time and adjust to meet the demand pattern as witnessed by the actual passenger loads. Passenger loads can also be stored as historical data and used as the basis for both short- and long-term demand predictions. These can be utilized to improve the planning process for public transportation operations. Another use of this information involves the allocation of public transportation financial subsidies. Many privately operated transportation companies receive subsidies on the basis of number of passengers carried. This is usually part of a wider traffic demand management strategy aimed at encouraging the use of public transportation. In these cases, the passenger count information can be used to ensure accurate disbursement of the subsidy.

Transit Vehicle Tracking. Transit vehicle tracking enables the tracking of vehicle locations, development and maintenance of delivery itineraries, and fuel usage monitoring. In-vehicle equipment ranges from relatively simple devices to measure distance traveled and fuel used to more sophisticated units using GPS, dead reckoning, and/or map-matching techniques. Beacon-based vehicle-to-roadside communication technologies can also be deployed to provide vehicle location to the fleet management center.

Commercial Vehicle Operations

Several market packages relate to commercial vehicle operations (CVO). Those seemingly appropriate for application in the GYRITS Corridor include the following:

- CVO Fleet Maintenance
- Driver Visibility Improvement (previously defined)
- Electronic Clearance Enrollment (previously defined)
- Freight Administration
- Driver Safety Monitoring (previously defined)
- Electronic Clearance
- Fleet Administration
- HAZMAT Management

- Lateral Safety Warning (previously defined)
- Longitudinal Safety Warning (previously defined)
- On-Board CVO Safety
- Roadside CVO Safety
- Vehicle Safety Monitoring (previously defined)
- Weigh-in-motion

CVO Fleet Maintenance. Fleet maintenance supports the maintenance of fleet vehicles by interfacing with on-board monitoring equipment and vehicle location technologies (i.e., AVL). Vehicle mileage, repair, and safety violation records are maintained to assure safe vehicles on the highway.

Electronic Clearance. Electronic clearance provides for automated clearance at roadside check facilities such as weigh stations or ports of entry. This market package allows a good driver/vehicle/carrier to pass roadside facilities using vehicle-to-roadside devices and communications such as transponders and dedicated short-range communications (DSRC) to the roadside. The roadside check facility may be equipped with automatic vehicle identification (AVI), weighing sensors, transponder read/write devices, computer workstation processing hardware, software, databases, or combinations thereof.

Fleet Administration. Fleet administration provides vehicle condition monitoring and maintenance scheduling functions to public transport operators. These include both real-time and "off-line" processes such as task and technician scheduling and monitoring. Sensors on board the vehicle can include transducers, temperature gauges, door mechanism sensors, tire pressure gauges, and engine management systems including emissions monitoring.

An on-board microprocessor polls each of these sensors and determines if there are any irregularities. The on-board processor can also prepare summary reports of historical sensor data that can be stored on board the vehicle for later retrieval and analysis. This analysis can be performed by an expert system that provides predictions of failure rates and anticipates the need to repair key components. This is interfaced with the work scheduling activities to effectively plan repair workloads. Linked to an inventory control system, this market package can also reduce the need for parts inventory by making more accurate estimates of parts requirements.

Freight Administration. Freight administration tracks cargo location and condition. This information is communicated with a fleet and freight management center via the existing wireless infrastructure. Interconnections are provided to freight shippers for tracking cargo across modes as it moves from origin to destination.

HAZMAT Management. HAZMAT management integrates incident management capabilities with commercial vehicle tracking to ensure effective treatment of hazardous material incidents. If an incident occurs, emergency personnel are notified and the proper response is coordinated based on information provided.

On-board CVO Safety. On-board CVO safety is an enhancement of the Roadside CVO Safety market package and includes roadside support for reading on-board safety data via AVI transponders. This market package uses the same communication links as the Roadside CVO Safety market package and provides the commercial vehicle with a wireless link (data and possibly voice) to fleet/freight management centers and emergency management centers. Safety warnings are provided to the driver as a priority with secondary requirements to notify the fleet managers and the roadside inspection stations.

Roadside CVO Safety. Roadside CVO safety provides for automated roadside safety monitoring and reporting (i.e., it automates commercial vehicle safety inspections). The capabilities for performing the safety inspection are shared between this market package and the On-board CVO Safety market package, which enables a variety of implementation options.

The basic option, directly supported by this market package, facilitates safety inspection of vehicles that have been pulled in, perhaps as a result of an automated screening process. In this scenario, only basic identification data and status information is read from the AVI transponder on the commercial vehicle. The driver/vehicle/carrier identification data from the transponder allows access to additional, more comprehensive safety data maintained by the system.

Weigh-in-motion. Weigh-in-motion provides for high speed vehicle weighing. Weigh-in-motion equipment can be either fixed or mobile. Fixed implementations are typically used to supplement electronic clearance, working in conjunction with AVI and automatic vehicle

classification (AVC) equipment. Mobile installations can be used for data collection for selective enforcement programs.

Infrastructure Operations and Maintenance

Market packages related to infrastructure operations and maintenance for the GYRITS Corridor include the following:

- Broadcast Traveler Information (previously defined)
- Electronic Clearance (previously defined)
- HAZMAT Management (previously defined)
- Incident Management System (previously defined)
- Mobile Traffic Management/Enforcement (previously defined)
- Network Surveillance (previously defined)
- Probe Surveillance
- Roadside CVO Safety (previously defined)
- Surface Street Control
- Traffic Information Dissemination (previously defined)
- Virtual Traffic Management Center (previously defined)
- Weigh-in-motion (previously defined)

Probe Surveillance. Probe surveillance can be used to provide information related to location, path, time, temperature, dew point, and other environmental information as experienced by the vehicle. A vehicle-to-roadside communications link, used to relay information back to some central location like a traffic management center, can be achieved through the use of wireless communications such as cellular telephone and packet data radio.

Depending on the sophistication of the in-vehicle equipment, one or more of the following may be provided:

- travel times along links traversed by the probe vehicle,
- road surface conditions experienced by the probe vehicle,
- traffic speeds, and

- weather conditions.

Probe vehicle reporting can be carried out on a "by exception" basis under which the probe vehicle only reports conditions that lie within a pre-defined range, or tolerance band. This is useful in reducing the volume of messages handled by the communication network and control center. Probe vehicles can also be constrained to different reporting frequencies depending on geographical location, so that in areas with many probes, reporting is less frequent. Conversely, in areas with few probes, the vehicle can be asked to transmit more frequently.

An entire vehicle population could act as probes or a defined user fleet such as snowplows, maintenance vehicles, and taxis could be designated as probes. Current research indicates that a sample size of approximately two percent of the entire vehicle population may be enough to obtain reliable statistics.

Surface Street Control. Surface street control provides the communication links and the signal control equipment for local surface street control and/or arterial control.

Fleet Operations and Maintenance

Fleet operations and maintenance market packages deemed appropriate for the GYRITS Corridor include the following:

- CVO Fleet Maintenance (previously defined)
- Driver Safety Monitoring (previously defined)
- Electronic Clearance Enrollment (previously defined)
- Freight Administration (previously defined)
- Multimodal Coordination (previously defined)
- Roadside CVO Safety (previously defined)
- Demand Responsive Transit Operations (previously defined)
- Electronic Clearance (previously defined)
- Fleet Administration (previously defined)
- HAZMAT Management (previously defined)
- On-Board CVO Safety (previously defined)
- Transit Fixed-Route Operations (previously defined)

- Transit Maintenance
- Transit Passenger And Fare Management (previously defined)
- Transit Vehicle Tracking (previously defined)
- Vehicle Safety Monitoring (previously defined)

Transit Maintenance. Transit maintenance supports the maintenance of transit fleet vehicles through the use of on-board monitoring equipment and vehicle location and identification equipment (i.e., AVL). Records of vehicle mileage and repairs are maintained to ensure safe vehicles on the highway.

New Market Packages

As stated previously, the flexibility of the architecture allows the creation of new or modified market packages or to meet specific challenges when the technology solutions are available. A number of new market packages were created to meet specific rural challenges and priorities. These include the following:

- Animal-vehicle Collision Countermeasures
- Dynamic Warning Systems
- Emergency Vehicle Maintenance
- En-route Interactive Traveler Information
- Pre-trip Interactive Traveler Information
- Regional ITS Planning
- Roadside Traveler Information
- Safe Speed Advisory
- Safety for Commercial Vehicles
- Transit Vehicle Routing
- Vehicle Tracking and Dispatch

These new market packages are defined below. In addition, the relationship of these new market packages to the CPAs is provided in Table 8.

Animal-vehicle Collision Countermeasures. Animal-vehicle collision countermeasures will employ sensing technologies to detect animal encroachments within the right-of-way and give the driver more accurate and timely notification of a potential conflict. An animal alert warning system (AAWS) provides one technological alternative. The AAWS system uses a sensing technology to detect the presence of an animal and then relays this data to a communication

Table 8. Relating New Market Packages to Critical Program Areas

Market Packages \ Critical Program Areas	Traveler Safety and Security	Emergency Services	Tourism and Travel Information Services	Public Traveler Services/Public Mobility Services	Commercial Vehicle Operations	Infrastructure Operations and Maintenance	Fleet Operations and Maintenance
Animal-vehicle Collision Countermeasures	√						
Dynamic Warning Systems	√						
Emergency Vehicle Maintenance							√
En-route Interactive Traveler Information			√	√			
Pre-trip Interactive Traveler Information			√	√			
Regional ITS Planning	√	√	√	√	√	√	√
Roadside Traveler Information			√	√			
Safe Speed Advisory	√						
Safety for Commercial Vehicles					√	√	√
Transit Vehicle Routing				√			√
Vehicle Tracking and Dispatch					√		√

medium such as a blackout sign or illuminated beacons that are only active when an animal is present.

Dynamic Warning System. Dynamic warning systems will provide the traveler with a dynamic warning of an impending conflict based on the vehicle type, vehicle speed and/or weight and the corresponding roadway conditions, geometry, weather, or a combination of these factors. Sensing technologies, such as those used with road weather information systems (RWIS) could be used to determine data elements such as visibility, roadway condition, and surface temperature. This market package could also be used in applications involving non-standard vehicle types (i.e., snowmobiles), intersection collision avoidance, and animal conflicts.

Emergency Vehicle Maintenance. (4) Emergency vehicle maintenance provides the functionality to support automated vehicle maintenance planning through the use of vehicle mileage, vehicle condition monitoring, and maintenance schedule planning. It would typically be provided as an extension to emergency fleet management functions and utilizes the same in-vehicle and communication network equipment. Additional sensors would monitor parameters such as vehicle speed, brake wear, tire wear, engine management functions, total miles traveled, fuel consumption, and oil consumption. Additional software is required in the emergency management center to accept, process, and summarize this data.

En-route Interactive Traveler Information. (4) En-route interactive traveler information provides tailored responses to travelers' requests for information on traffic conditions, transit services, traveler services, rideshare/ride match, parking, and pricing. A range of two-way wide-area wireless communications systems may be used to support the required digital communications between traveler and the information service provider. To access information en-route, the traveler may use a variety of interactive devices including cellular phones, pagers, personal digital assistants, and a variety of in-vehicle devices. Successful deployment of this market package relies on availability of real-time transportation data from roadway instrumentation, probe vehicles, or other means.

Pre-trip Interactive Traveler Information. (4) Pre-trip interactive traveler information provides tailored responses to travelers' requests for information on traffic conditions, transit services, traveler services, rideshare/ride match, parking, and pricing. A range of two-way wide-area wireless communications systems may be used to support the required digital communications between a traveler and the information service provider. To access pre-trip information, a variety of interactive devices may be used by the traveler, including phone, kiosk, personal digital assistant, home/office computer, and Internet. Successful deployment of this market package relies on availability of real-time transportation data from roadway surveillance, probe vehicles, or other means.

Regional ITS Planning. (4) Regional ITS planning facilitates the application of ITS solution methods into the planning process. While not a technology-based market package, ITS planning

plays a vital role in the implementation of ITS systems, as well as the future plans throughout a region where ITS is to be deployed.

Roadside Traveler Information. (4) Roadside traveler information allows traffic information to be disseminated using roadway equipment such as changeable message signs or highway advisory radio. Providing basic traffic information, such as incidents, congestion, and delays, is a priority using minimal or no in-vehicle equipment. Careful placement of the roadway equipment provides the information at points in the network where the drivers have recourse and can tailor their routes to account for the new information. This package could also ensure that information is available in a format for media usage, such as a fax output or a direct tie-in to radio and television station computer systems.

Safe Speed Advisory. Safe speed advisory will provide vehicles with information necessary to safely navigate steep grades and sharp curves found in canyons and on mountain passes. The technology will include weigh-in-motion and a variable message sign displaying the maximum safe speed. The data processing will incorporate vehicle configuration, weight, and roadway geometry in order to determine the maximum safe speed for each vehicle.

Safety for Commercial Vehicles. (4) Safety for commercial vehicles provides functions for on-board safety monitoring for commercial vehicles and automated reporting of safety status. It also provides roadside support for reading on-board safety data and facilities automated inspections at the roadside.

Sensors on board the vehicle monitor critical safety components such as brakes, headlights, steering, indicators, and engine management system functions. Sensors on the loading area also monitor the stability and equilibrium of the cargo. The number of consecutive driving hours performed by the operator can also be measured by integrating a tachograph with the sensor package. This information is stored electronically on board the vehicle and transmitted to both the fleet management center and local roadside inspection stations as required. In the fleet management center, the data is accepted and processed by hardware and software with action items determined and reported to the management center operating staff.

For hazardous material transport applications, information concerning safe handling techniques for the cargo would also be stored electronically on board the vehicle.

Transit Vehicle Routing. (4) Transit vehicle routing builds upon the Transit Vehicle Tracking market package by adding a routing function. As the position of the vehicle is monitored, so are the surrounding traffic conditions. This

is sent to a management center where optimum or alternative routes are developed using algorithms. The routing information is then transmitted to the transit vehicle via wireless technology.

Vehicle Tracking and Dispatch. (4) Vehicle tracking and dispatch provides functions that enable the tracking of goods and vehicles, development and maintenance of delivery itineraries, and fuel usage monitoring. The core of this package is a fleet management center that accommodates the automatic vehicle location system, and fleet management hardware and software to capture and process vehicle location data and perform fleet management processes. In-vehicle equipment will range from relatively simple devices to measure distance traveled and fuel used to more sophisticated units using GPS, dead reckoning, and/or map matching techniques.

SELECTING PRIORITY MARKET PACKAGES FROM RURAL MODEL ARCHITECTURE

Recall that a regional architecture relies on a model system architecture for organization and functionality. The regional architecture development process reduces the set of possible solutions according to specific challenges and regional goals. The result is a set of grouped solution technologies that address specific *regional* challenges. A regional architecture is compatible with the system architecture but is specific to each corridor, region, or project.

The GYRITS Corridor Regional Architecture development process to date has considered GYRITS Corridor specific challenges, related these to the larger NSA model architecture, and adjusted the NSA model architecture to better reflect rural conditions. The previous section defined applicable market packages for rural environments and grouped these market packages into areas of focus (i.e., Critical Program Areas). This, in essence, comprises the rural model architecture on which the GYRITS Corridor Regional Architecture will be based.

The next step in the process is to use the adjusted model architecture to once again focus on Corridor specific challenges. A subset of market packages from the rural model architecture was selected that best address the specific Corridor challenges (Step 5 in Figure 3).

Prioritizing Market Packages

Prioritization of the market packages to determine which best address the identified Corridor challenges is the next step in the GYRITS Corridor Regional Architecture development process. This prioritization must identify market packages that are feasible for implementation and that address the Corridor specific challenges and project goals and objectives.

In order to prioritize the market packages, the following criteria were utilized:

- the market package should directly or indirectly address the needs of the traveler,
- the market package should address specific Corridor challenges as determined in Task 3, and
- the market package should have a high chance of success.

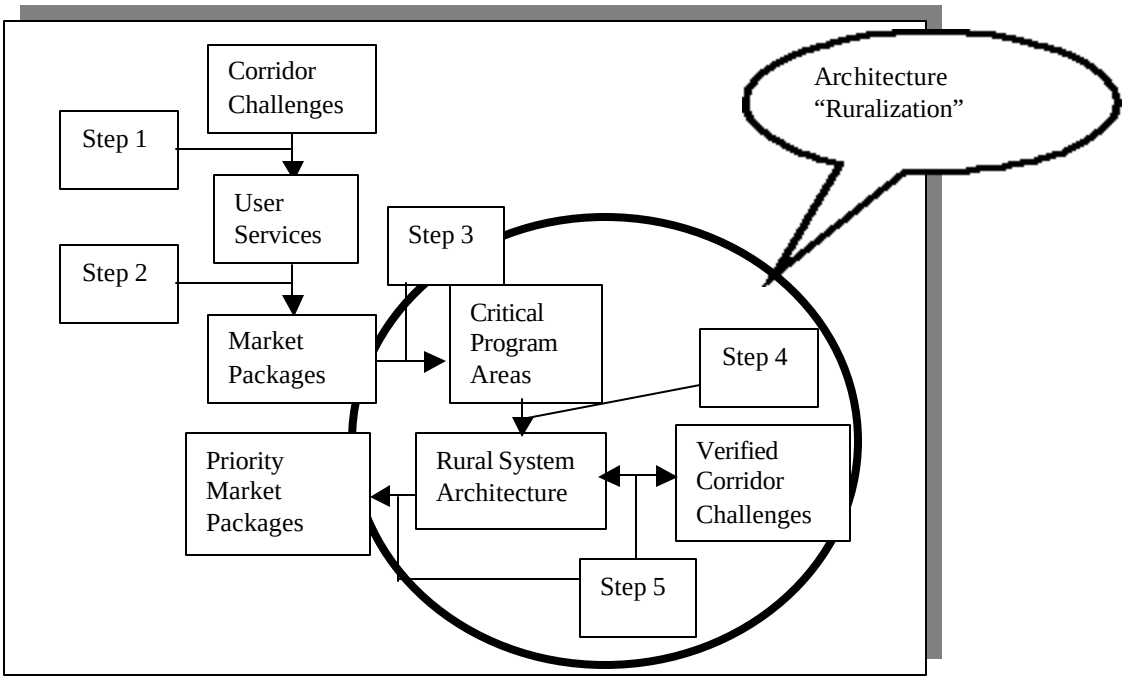

Figure 3. ArchitectureDevelopment Process (repeated)

The following section summarizes the market packages, identified as a priority, for each of the previously identified Corridor challenges. The process of associating the market package that would best address the Corridor challenges was largely intuitive, relying on the technical merit and feasibility of application of the market package to the given challenge. Examples of potential ITS infrastructure is provided to help bridge the gap between deployment of infrastructure and the architectural elements.

Inclement Weather Challenge

Priority market packages for addressing problems with inclement weather are summarized in Table 9. Inclement weather affects driver visibility and road conditions. By increasing traveler information quantity, quality, and availability, travelers will be able to make more informed decisions about route choice and departure times. Technologies available in the Network Surveillance and Probe Surveillance market packages will allow the collection and dissemination of traffic, road, and weather conditions, and predict future changes. The Traction Control and Driver Visibility Improvement market packages will focus on improving vehicle and driver capabilities for the private and commercial traveler. Information should be made available to the

Table 9. Priority Market Packages for Addressing Inclement Weather

Critical Program Areas / Market Packages	Traveler Safety and Security	Emergency Services	Tourism and Travel Information Services	Public Traveler Services/Public Mobility Services	Commercial Vehicle Operations	Infrastructure Operations and Maintenance	Fleet Operations and Maintenance
Broadcast Traveler Information			√			√	
Interactive Traveler Information			√				
Network Surveillance	√					√	
Probe Surveillance						√	
Safe Speed Advisory	√				√		
Traffic Information Dissemination	√		√			√	

regional traveler, the tourist, and the local traveler through multiple and redundant systems that will ensure accuracy, reliability, and timeliness.

Development of an interactive, integrated road weather information system (RWIS) system will enable weather and roadway condition information to be gathered and disseminated through several different media that may include Internet, cable TV, and fax. This implementation could also include the integration of a Virtual Traffic Management Center (TMC)(i.e. regional server) to aid in operation and control of the information supplied through the environmental sensors that make up the core of the RWIS. This one implementation illustrates the interdependence of systems, operations, and potential level of coordination involved with the regional architecture and deployment.

Unsafe Speed Challenge

Travelers often are not cognizant of the hazards associated with traveling at a high rate of speed through construction work zones, on icy roads, and/or during dusk and dawn. The abolition of

Montana's numerical daytime speed limit in 1995, coupled with state daytime speed limits in Idaho and Wyoming, add to the confusion of tourists and travelers unfamiliar with the area. Mobile traffic management strategies and mobile enforcement can help to alleviate this problem (see Table 10). In instances where unaware travelers may be traveling at an unsafe speed for the road conditions, the Traction Control market package may help the driver to maintain control of the vehicle when decelerating and accelerating, thus, increasing safety by decreasing the occurrence of several types of accidents.

One potential solution includes the deployment of a safe speed advisory system. Such a system would use real-time vehicle speed and weight data collected through weigh-in-motion (WIM) devices and loop detectors to detect vehicles traveling at unsafe speeds and recommend a speed safe for the geometric and conditional limitations of the roadway.

Table 10. Priority Market Packages for Addressing Unsafe Speeds

Critical Program Areas / Market Packages	Traveler Safety and Security	Emergency Services	Tourism and Travel Information Services	Public Traveler Services/Public Mobility Services	Commercial Vehicle Operations	Infrastructure Operations and Maintenance	Fleet Operations and Maintenance
Dynamic Warning System	√						
Mobile Traffic Management/Enforcement	√						
Safe Speed Advisory	√				√		
Traction Control	√						

Commercial Vehicle Safety Challenge

Commercial vehicle operations (CVO) in and around the GYRITS Corridor significantly impact travelers' perceptions of safety. While commercial vehicle accident rates throughout most of the Corridor are not significantly higher than the national average (5), the higher severity of most commercial vehicle accidents makes them of greater concern. Also of concern is the amount of infrastructure damage resulting from overweight vehicles on Corridor roadways.

From an enforcement standpoint, mobile enforcement units, weigh-in-motion (WIM), and roadside safety checks help to ensure safe operations of commercial carriers (see Table 11). Most carriers have a vested interest in improving safety and operations of their drivers and fleet. Several rural market packages will enable the implementation and operation of ITS that will increase driver and vehicle safety, thereby improving operations. Implementation options include partial automation of key weigh stations in and around the Corridor. This would greatly increase the efficiency and effectiveness of CVO enforcement efforts by freeing up enforcement officers to perform safety checks and allowing selective enforcement of problem carriers.

Table 11. Priority Market Packages for Addressing Commercial Vehicle Safety

Critical Program Areas / Market Packages	Traveler Safety and Security	Emergency Services	Tourism and Travel Information Services	Public Traveler Services/Public Mobility Services	Commercial Vehicle Operations	Infrastructure Operations and Maintenance	Fleet Operations and Maintenance
CVO Fleet Maintenance					√		√
Driver Safety Monitoring	√				√		√
Mobile Traffic Management/Enforcement	√						
On-board CVO Safety					√		√
Roadside CVO Safety					√	√	√
Weigh-in-motion					√	√	

Hazardous Materials Challenge

The transfer of hazardous materials through the GYRITS Corridor is a very sensitive issue. Transfer of hazardous materials through Yellowstone National Park (YNP) is prohibited and can only take place under very specific circumstances.

The most desirable solution is to avoid HAZMAT incidents; mobile enforcement can help to achieve this goal (see Table 12). In the event of an incident in the Corridor, several potential ITS technologies will enable a coordinated response including the solutions within the HAZMAT Management and Incident Management rural market packages.

Emergency Response Time Challenge

Due to the rural nature of the GYRITS Corridor, long distances between towns and emergency services is a reality that affects nearly every incident. Long response times are troublesome if someone is critically injured and medical attention is delayed. Infrequent traffic and limited cellular coverage in some areas also lengthen incident detection times. Location information can be limited, and coordination of the response is often less than optimal.

Table 12. Priority Market Packages for Addressing Hazardous Materials

Critical Program Areas / Market Packages	Traveler Safety and Security	Emergency Services	Tourism and Travel Information Services	Public Traveler Services/Public Mobility Services	Commercial Vehicle Operations	Infrastructure Operations and Maintenance	Fleet Operations and Maintenance
HAZMAT Management					√	√	√
Incident Management System	√					√	
Mobile Traffic Management/Enforcement	√						

Table 13 summarizes suitable market packages for addressing emergency response issues. In most areas, Emergency Response, Emergency Routing, and Mayday Support systems will significantly improve the degree of coordination and long emergency response times. Coordination through a Virtual TMC will help to ensure coordinated and adequate response to each incident. The implementation of these systems will add value to training, operations, and technology already in use for emergency response.

Traveler/Tourist Information Challenge

The availability, reliability, accuracy, and quality of information for travelers is of paramount importance, as it enables sound decision-making by travelers. Two primary types of information are needed within the Corridor: (1) tourist information, including services; and (2) weather-related information, including road conditions.

Table 13. Priority Market Packages for Addressing Emergency Response Times

Critical Program Areas / Market Packages	Traveler Safety and Security	Emergency Services	Tourism and Travel Information Services	Public Traveler Services/Public Mobility Services	Commercial Vehicle Operations	Infrastructure Operations and Maintenance	Fleet Operations and Maintenance
Emergency Response	√	√					
Emergency Routing		√					
Incident Management System	√					√	
Mayday Support	√	√					
Virtual TMC		√				√	

Table 14. Priority Market Packages for Addressing Traveler/Tourist Information

Critical Program Areas / Market Packages	Traveler Safety and Security	Emergency Services	Tourism and Travel Information Services	Public Traveler Services/Public Mobility Services	Commercial Vehicle Operations	Infrastructure Operations and Maintenance	Fleet Operations and Maintenance
Broadcast Traveler Information			√			√	
Interactive Traveler Information			√				
Network Surveillance	√					√	
Probe Surveillance						√	
Virtual TMC		√				√	
Yellow Pages and Reservation			√				

The dissemination of this information can be accomplished using several market packages, including Traffic Information Dissemination, Broadcast Traveler Information, Interactive Traveler Information, and the Yellow Pages and Reservation (see Table 14). Data collection and distribution technologies necessary for the successful implementation of the system include Network Surveillance, Probe Surveillance, and the Virtual TMC market packages. Integration with an interactive RWIS will facilitate full implementation of the necessary information delivery technologies such as Internet and kiosks.

Failure to Yield Right-of-way/Disregard for Traffic Control Challenge

Accidents in urban areas are often result from motorists disregarding traffic control or failing to yield the right-of-way to oncoming traffic. The root cause may be inattentive driving. While ITS technologies may have limited applicability for this challenge, one technology-based solution that could help is the Intersection Collision Avoidance market package (see Table 15). This package may aid in the avoidance of collisions at or near intersections where the majority of

failure-to-yield accidents take place. Deployment of this market package includes in-vehicle sensory equipment. Enhanced enforcement may also help to decrease traffic violations of this nature.

Rear-end Collision Challenge

Rear-end collisions within the Corridor are a problem due to several factors such as icy roads, poor visibility, driver inattentiveness, and others, or a combination thereof. The Intersection Collision Avoidance, Intersection Safety Warning, Pre-crash Restraint Deployment, and Driver Visibility Improvement market packages all contain elements that may help alleviate the cause and/or effects of rear-end collisions (see Table 16).

Animal Encroachment on the Roadway Challenge

Encroachment of animals on the roadway is a significant problem in some areas of the Corridor. Historically, solutions have attempted to alert the animal of a vehicle's presence and either scare it away from the roadway or prevent further encroachment. However, addressing this problem with available and emerging technologies in the Longitudinal Safety Warning, Lateral Safety Warning, and Animal-Vehicle Collision Countermeasures market packages could shift focus to warning the driver of animal presence rather than warning the animal of vehicle presence (see Table 17).

Snowmobile Crash Challenge

Conflicts with non-standard vehicles such as snowmobiles are a significant safety challenge within areas of the Corridor and during certain times of the year. Four market packages can help address this challenge: Longitudinal Safety Warning, Lateral Safety Warning, Intersection Collision Avoidance, and Dynamic Warning System (see Table 18). The Dynamic Warning system could include an intrusion detection technology with a dynamic signing system to alert the driver of an eminent collision. By allowing slightly more warning of the non-standard vehicle's presence, many of these conflicts may be avoided.

Table 15. Priority Market Packages for Addressing Failure to Yield Right-of-way/Disregard for Traffic Control

Critical Program Areas / Market Packages	Traveler Safety and Security	Emergency Services	Tourism and Travel Information Services	Public Traveler Services/Public Mobility Services	Commercial Vehicle Operations	Infrastructure Operations and Maintenance	Fleet Operations and Maintenance
Intersection Collision Avoidance	√						
Mobile Traffic Management/Enforcement	√						

Table 16. Priority Market Packages for Addressing Rear-end Collisions

Critical Program Areas / Market Packages	Traveler Safety and Security	Emergency Services	Tourism and Travel Information Services	Public Traveler Services/Public Mobility Services	Commercial Vehicle Operations	Infrastructure Operations and Maintenance	Fleet Operations and Maintenance
Driver Visibility Improvement	√				√		
Intersection Collision Avoidance	√						
Intersection Safety Warning	√						
Pre-Crash Restraint Deployment	√						

Table 17. Priority Market Packages for Addressing Animal Encroachments on the Roadway

Critical Program Areas / Market Packages	Traveler Safety and Security	Emergency Services	Tourism and Travel Information Services	Public Traveler Services/Public Mobility Services	Commercial Vehicle Operations	Infrastructure Operations and Maintenance	Fleet Operations and Maintenance
Animal-vehicle Collision Countermeasures	√						
Lateral Safety Warning	√				√		
Longitudinal Safety Warning	√				√		

Table 18. Priority Market Packages for Addressing Snowmobile Crashes

Critical Program Areas / Market Packages	Traveler Safety and Security	Emergency Services	Tourism and Travel Information Services	Public Traveler Services/Public Mobility Services	Commercial Vehicle Operations	Infrastructure Operations and Maintenance	Fleet Operations and Maintenance
Dynamic Warning System	√						
Intersection Collision Avoidance	√						
Lateral Safety Warning	√				√		
Longitudinal Safety Warning	√				√		

Commercial Vehicle Efficiency Challenge

The GYRITS Corridor is composed of two primary routes for the movement of commercial goods. I-90 is the primary east-west route through Montana, connecting the West Coast to Midwest markets. I-15 is a vital link in the CANAMEX Corridor, which connects Canadian and Mexican markets to and through the U.S. U.S. 191 and U.S. 89 are also vital routes serving several large communities within the region. Several market packages are available to help increase the efficiency of CVO, including Electronic Clearance, Weigh-in-motion (WIM), and Fleet and Freight Administration (see Table 19).

Table 19. Priority Market Packages for Addressing Commercial Vehicle Efficiency

Critical Program Areas / Market Packages	Traveler Safety and Security	Emergency Services	Tourism and Travel Information Services	Public Traveler Services/Public Mobility Services	Commercial Vehicle Operations	Infrastructure Operations and Maintenance	Fleet Operations and Maintenance
CVO Fleet Maintenance					√		√
Electronic Clearance					√	√	√
Electronic Clearance Enrollment	√				√		√
Fleet Administration					√		√
Freight Administration					√		√
Vehicle Tracking and Dispatch					√		√
Weigh-in-motion					√	√	

Traveler Mobility Challenge

In the counties surrounding the GYRITS Corridor, 10 percent of the population are over age 65, 15 percent of the population have incomes below the poverty level, and 3 percent have a physical mobility limitation (6). Many of these citizens are dependent on public transportation for healthcare, shopping, and other activities important to the quality of life. Although six paratransit services operate within the Corridor, they provide limited hours of operation and service areas. Technology could improve the matching of riders with public transit vehicles and improve transit system management through improved routing and scheduling (see Table 20).

Table 20. Priority Market Packages for Addressing Traveler Mobility

Critical Program Areas / Market Packages	Traveler Safety and Security	Emergency Services	Tourism and Travel Information Services	Public Traveler Services/Public Mobility Services	Commercial Vehicle Operations	Infrastructure Operations and Maintenance	Fleet Operations and Maintenance
Demand Responsive Transit Operations				√			
Dynamic Ridesharing			√	√			
Multimodal Coordination							√
Traffic Information Dissemination	√		√			√	
Transit Fixed-Route Operations				√			√
Transit Passenger and Fare Management				√			√
Transit Vehicle Tracking							√
Vehicle Tracking and Dispatch							√

Yellowstone National Park Entrance Congestion Challenge

Entrance gates at Yellowstone National Park (YNP) experience relatively severe congestion during the peak tourist season. Geometric improvements in these locations certainly have merits, but application of simple ITS solutions should not be overlooked. Mobile traffic management strategies, traffic information dissemination, facility use management, and transit management could all play a role in alleviating the congestion problems at the gates of Yellowstone National Park. One particular technology with merit is electronic clearance for local travelers who must pass through the gates regularly. Through the application of some or all of the market packages listed in Table 21, use of YNP gates may be made more efficient and improve the overall experience in Yellowstone National Park.

Table 21. Priority Market Packages for Addressing Yellowstone National Park Entrance Congestion

Critical Program Areas / Market Packages	Traveler Safety and Security	Emergency Services	Tourism and Travel Information Services	Public Traveler Services/Public Mobility Services	Commercial Vehicle Operations	Infrastructure Operations and Maintenance	Fleet Operations and Maintenance
Facility Use/ Parking Fee Management			√				
Mobile Traffic Management/Enforcement	√						
Traffic Information Dissemination	√		√			√	
Transit Fixed-Route Operations							√

Construction Zone Congestion Challenge

Congestion and delays at construction zones are often inevitable. Traveler frustration and impatience is often directly related to the quantity, quality, and availability of information related to the delays. Mobile traffic management strategies could reduce some delay, but traffic information dissemination will play a vital role in alleviating traveler frustration with construction delays (see Table 22).

Tourism and Economic Development Challenge

Tourism and economic development within the Corridor are very important to the success of any ITS projects. Local economies will likely be affected, either directly or indirectly, through implementation of ITS. Market packages intended to address challenges related to tourism and economic development are provided in Table 23. These market packages can be integrated into a smart card system in which traveler patronage and use can be rewarded and documented.

Table 22. Priority Market Packages for Addressing Construction Zone Congestion

Critical Program Areas / Market Packages	Traveler Safety and Security	Emergency Services	Tourism and Travel Information Services	Public Traveler Services/Public Mobility Services	Commercial Vehicle Operations	Infrastructure Operations and Maintenance	Fleet Operations and Maintenance
Mobile Traffic Management/Enforcement	√						
Traffic Information Dissemination	√		√			√	

Table 23. Priority Market Packages for Addressing Tourism and Economic Development

Critical Program Areas / Market Packages	Traveler Safety and Security	Emergency Services	Tourism and Travel Information Services	Public Traveler Services/Public Mobility Services	Commercial Vehicle Operations	Infrastructure Operations and Maintenance	Fleet Operations and Maintenance
Facility Use/ Parking Fee Management			√				
Transit Passenger and Fare Management							√

IMPLEMENTATION CONSIDERATIONS

To enable effective implementation of rural ITS solutions, it is necessary to identify the solutions that best address traveler needs within the Corridor. The previous section described priority market packages to address Corridor challenges. This section will describe considerations that should be taken into account prior to any actual implementation. In fact, these considerations may help in directing the selection of systems for implementation.

Two primary issues will be considered in this section, including:

- the ability to evaluate the performance of the system through the identification and attainment of specific measures of effectiveness, and
- the availability of communication technology alternatives.

Measures of Effectiveness

An important consideration when implementing rural ITS is the ability to judge the performance of the system. This ability is important not only to support the decision made at that locale but also to encourage the implementation of ITS in other rural locations and potentiallly the technology utlilized.

To some extent, the ability to judge the performance of a system can be determined intuitively prior to implementation through pre-defined measures of effectiveness (MOEs). Projects that have a high level of anticipated benefits and a high likelihood for quantification of these benefits will be viewed as priority implementations. The defined measures of effectiveness should relate directly to the regional goals. Similar measures of effectiveness may apply to several goals. As such, the set of MOEs may be substantially less in number than the regional goals.

Several factors influence the ability to judge the performance of a system. These include: (1) the ability to define specific, easily understood measures of effectiveness for a particular goal, (2) the availability of existing data to support the measures of effectiveness, and (3) the ease of acquisition for data that is not currently available but necessary to support the measures of effectiveness.

Table 24 contains the preliminary measures of effectiveness linked to the various Corridor challenges previously defined (project goals are related to these Corridor challenges by assuming a desire to improve (1) safety-related challenges by reducing the number or severity of crashes or (2) operational efficiency by reducing delay). In general, the measures of effectiveness proposed for GYRITS Corridor ITS implementation relate to the following:

- crash frequency and severity;
- frequency of erratic or improper traffic maneuvers (i.e., excessive speeds for conditions, disregard for traffic control);
- incident notification and response times and cleanup costs;
- vehicle delay resulting from excessive demand (i.e., weigh stations or ports of entry and tourist attractions) or restricted capacity (i.e., construction zones);
- transit ridership; and
- tourism volumes and spending.

Communication Technology Alternatives

A second factor affecting rural ITS implementation relates to communication technology alternatives. The feasibility of various communication technologies may depend highly on the existing communications infrastructure within the Corridor as well as geographic constraints. By determining the communications technology available, the type and extent of existing infrastructure, and the requirements of the individual ITS applications, the feasibility of Corridor projects may be further assessed.

General Communication Concepts and Alternatives

Communications alternatives can be classified into two major divisions: wireless and wire-line. Wireless communications occur by transmitting a signal through the air to a receiver. Wire-line communications use a physical connection to transmit information. A cursory discussion of range, signal, and transmission options is provided below.

Table 24. Measures of Effectiveness, Data Sources and Availability

CORRIDOR CHALLENGES	MOEs	DATA SOURCES														DATA AVAILABILITY						
		User Surveys	Speed Study	Traffic Counts	Port of Entry Data	Weigh-in-Motion Data	Card Transaction Data	Idaho DOT	Montana DOT	Wyoming DOT	Yellowstone National Park	USDOT	State Department of Environmental Quality	State Tourism Agencies	Paratransit Agencies	Already Available	Available, but possibly inaccurate	Only in aggregated form	For most locations	Requires staff time	Requires system deployment	To be determined
Inclement Weather	User convenience	√																		√		
Unsafe Speeds On Icy Roads	Travel speed (spot location)		√																	√		
	Accidents							√	√	√	√					√						
Commercial Vehicle Safety	Travel speed of commercial vehicles		√																	√		
	Accidents of commercial vehicles							√	√	√	√					√						
Hazardous Material Incidents	Number of incidents											√	√				√					
	Cost of cleanup											√					√					
Emergency Response Time	Average length of response time							√		√						√						
	Average length of notification time							√		√						√						
Lack Of Traveler/Tourist Information	Tourist dollars spent													√				√				
	Annual visitation													√					√			
Failure To Yield Right-of-way Or Disregard For Traffic Control	Number of vehicles incorrectly entering intersections (spot)			√																√		
	Accidents							√	√	√	√					√						

Table 24. Measures of Effectiveness, Data Sources and Availability (Continued)

CORRIDOR CHALLENGES	MOES	DATA SOURCES														DATA AVAILABILITY						
		User Surveys	Speed Surveys	Traffic Counts	Port of Entry Data	Weigh-in-Motion Data	Card Transaction Data	Idaho DOT	Montana DOT	Wyoming DOT	Yellowstone National Park	USDOT	State Department of Environmental Quality	State Tourism Agencies	Paratransit Agencies	Already Available	Available, but possibly inaccurate	Only in aggregated form	For most locations	Requires staff time	Requires system deployment	To be determined
REAR-END COLLISIONS	Accidents							√	√	√	√					√						
Animal Encroachment on the Roadway	Accidents							√	√	√	√					√						
Snowmobile Crashes	Accidents										√					√						
Commercial Vehicle Efficiency and Infrastructure Damage	POE delay times			√																√		
	POE volumes			√																√		
	Percent overweight				√	√														√		√
Traveler Mobility	Ridership														√	√						
	Operating Costs														√	√						
Congestion at Yellowstone National Park Entrances	Volumes			√																√		
	Delay times			√																√		
Congestion at Construction Zones	Volumes			√																√		
	Delay times			√																√		
Tourism and Economic Development	Use						√														√	

Range. Range is the performance of a communication technology—the maximum distance at which the communication is effective and clear. For simplicity, range is generalized as either short or long. Short-range communications take place in a very localized area. Vehicle-to-roadside communication in an automated toll collection application is an example of short-range communication. Usually, the effective communication zone is between 100 and 200 meters. Long-range communication technologies can also be effective as short-range communication. Broadcast media such as FM radio and two-way techniques such as cellular radio typify applications in this classification.

Signal. Communication signals can be either analog or digital. Analog signals are transmitted as continuous waves. The amplitude of frequency of the analog wave is altered to convey the data. Digital signals are made of small, discrete data elements that represent numerical codes or values. The translation of these signals at each end of the transmission converts the signal into meaningful communications.

Transmission. Single direction communication from transmitter to receiver is one-way technology. One-way transmission is sometimes called downlink communication and includes broadcast radio and TV. Communication technologies that enable transmission of voice or data in both directions are two-way communications, sometimes called uplink and downlink. Transmission and reception functions are performed through a transceiver and include technologies such as telephones. Table 25 provides examples of one-way and two-way communications.

Existing and Planned Communications Infrastructure

As part of Task 3, existing and planned communications infrastructure in the GYRITS Corridor was documented. This information was spatially recorded using GIS. The GIS data collection efforts included a manual survey of existing telephone service, power lines, and cellular coverage, and a review of data provided by various agencies. Further investigation of 24-hour radio dispatch centers, microwave towers, fiber-optic cable installations, and other existing communications infrastructure may be necessary as specific projects are defined and capital equipment is deployed.

Priority Market Package Communication Requirements

While several communications technologies are able to fulfill the requirements of the various market packages, the specific communications technology to be used in each application will not be specified until nearer implementation. This postponement is intended to prevent the specification of obsolete technology. As such, WTI will identify specific communication requirements at the project level later in the overall effort.

It is useful, however, to consider general communication alternatives appropriate for the GYRITS Corridor. Table 26 summarizes potentially viable technologies for each priority market package, taking into consideration challenges and limitations specific to the GYRITS Corridor.

Table 25. One-way and Two-way Transmission Options (7)

One-way Transmission Options	
Amplitude modulation (AM) radio	analog radio technique that uses signal amplitude to transmit data
Area radio networks (ARN)	broadcasts signal to an area, rather than a specific location, terrain barriers may limit the feasibility of this technology
FM side-band or automatic highway advisory radio (AHAR)	superimposes inaudible signals of a higher frequency superimposed on the normal FM broadcast
Highway advisory radio (HAR)	uses special broadcast frequencies for transmission of traffic and road condition information, relatively inexpensive
Radio paging information systems	collects sensory data at a control center, formats a useable message, or narrative, and broadcasts this information to equipped vehicles
Coaxial cable	used in tunnels and other areas where wide-area communications are ineffective
Cable television	allows video/television images to be distributed over a local area, rather than broadcast from a transmitter, has two-way communication potential
Videotext	data is carried or piggybacked on television signal transmission
Digital audio broadcasting	uses full digital transmission techniques to deliver voice and data via radio
Direct broadcast satellite TV	allows the reception of TV broadcasts via satellite and a special receiver, or dish, that allows reception of the signal
Two-way Transmission Options	
Dedicated land (telephone) lines	represents the most prevalent form of traffic control systems communication media
Coaxial cable	provides the communications media for many control applications, including video surveillance and traffic control systems
Fiber optics communications systems	provides high volume, cost-effective trunks for voice and data, used in local- and wide-area networks, point-to-point data communications links, and cable TV trunks and distribution networks
Serial wire-line (RS-232)	simplest communication technology, involves a cable that connects two computers together, allowing data transfer between the two computers
Beacon-based communications	roadside facilities that communicate in one or two directions through either a fixed network with centrally located, or disperse control units, or an 'air interface' with passing vehicles within a small contact area, can be stand-alone entities, or they may be a part of an extensive and complex system
In-vehicle transceivers	often referred to as "tags," first generation tags have simple ID codes and are mainly used by commuters on open toll systems, second generation tags are read/write tags and use some form of two-way communication link between the vehicle and roadside, third generation tags are flexible modular products with high-speed vehicle-to-roadside communication links, security protocol, smart card utilization, and well-developed driver interfaces
Packet data radio services	specifically designed for non-voice data transmission, similar to cellular radio, except for the techniques used to operate the communication links
Long-range microwave communications	used for point-to-point communication, primarily carrying voice and data transmission, requires a line-of-sight path between transmitting and receiving locations, limiting the technique in some locations
Spread spectrum radio	uses a technique that spreads a signal bandwidth over a wide range of frequencies at transmission, and then compresses the signal to the original frequency at the receiver
Analog cellular radio	the largest wireless communication network currently operating in the US, involves division of a coverage area into several small cells, each having its own low-power transmitter, coverage can be limited in rural areas due to geography and topography
Cellular digital packet data	a wireless packet data transmission for analog radio system users, the objective is to use available capacity in existing analog cellular networks to carry digitally encoded data
Personal communication services (digital cellular radio)	utilizes digital technologies to make cellular telephone services more efficient and better able to carry data, increases transmission capacities to several times those of analog systems

Table 26. Viable Communication Alternatives

CORRIDOR CHALLENGES	COMMUNICATION ALTERNATIVES						VIABLE TECHNOLOGY ALTERNATIVES																		
	Wire-line	Wireless	One Way	Two Way	Short-range	Long-range	Microwave Beacons	Infrared Beacons	RF Beacons	AM Radio	FM Radio	Area Radio Networks	HAR	TV	Cellular	FM Sideband	Direct Broadcast Satellite TV	Serial Wire-line RS 232	Telephone Lines	Coaxial Cable	Fiber Optic	Cable TV	Internet and On Line Services	Packet Data Radio	Spread Spectrum Radio	Trunked Radio Systems
Inclement Weather	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√			
Unsafe Weather	√	√	√		√		√	√	√	√	√				√	√		√	√	√	√					
Safety Problems Relating to Commercial Vehicles	√	√	√	√	√	√	√	√	√	√	√				√	√		√	√	√	√			√	√	√
Hazardous Materials	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√			
Emergency Response Time	√	√	√	√		√	√	√	√		√	√	√	√	√	√		√	√	√	√				√	√
Lack of Traveler/Tourist Information	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√		√	√
Failure to Yield Right-of-way or Disregard for Traffic	√	√	√		√	√	√	√	√						√	√	√	√	√	√	√					
Rear-End Collisions		√	√	√	√		√	√	√																	
Animal Encroachment on the Roadway	√	√	√	√	√	√	√	√	√				√		√			√	√	√	√					
Snowmobile Conflicts	√	√	√	√	√	√	√	√	√				√		√			√	√	√						
Commercial Vehicle Efficiency	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√		√	√	√	√		√	√	√	√
Traveler Mobility	√	√	√	√		√				√	√	√	√	√	√	√	√		√	√	√	√	√			
Congestion at Yellowstone National Park Entrances	√	√	√	√	√	√	√	√	√	√	√	√	√	√		√	√	√	√	√	√	√	√			
Congestion at Construction Zones	√	√	√		√	√	√	√	√	√	√	√	√	√		√	√	√	√	√	√	√	√			
Tourism and Economic Development	√	√	√	√	√	√	To Be Determined																			

SUMMARY AND NEXT STEPS

This report has described the regional architecture development process. While this report has not explicitly defined the GYRITS Corridor Regional Architecture, the necessary elements for its definition and development have been identified. This section summarizes the priority market packages for the GYRITS Corridor. These priority market packages will form the basis for the GYRITS Corridor Regional Architecture and will help to stage ITS implementation.

Summary of Priority Market Packages

By prioritizing the "rural" market packages and matching each with its corresponding Corridor challenges, the GYRITS Corridor Regional Architecture begins to take shape. The Corridor challenges were already associated with geographic areas of focus as part of Task 3. Hence, the market packages can now be associated with specific geographic areas of focus. Table 27 summarizes the priority market packages for each Corridor challenge.

Next Steps

The information contained in this report will support various future tasks in the GYRITS Priority Corridor Project. These include the following:

- Preliminary project identification and evaluation (Task 9),
- Preliminary project deployment (Task 10),
- Define regional architecture (Task 11),
- Develop ITS systems architecture and operations report (Task 12), and
- Evaluate systems and produce final report (Task 13)

Each of these tasks is more fully described below.

Task 9: Preliminary Project Identification and Evaluation

Task 9 will identify potential projects and record "before" conditions in the Corridor. Specific "early winner" projects will be defined that consider Corridor challenges, geographic areas of focus, and market packages. These projects will be detailed as to their location and their

Table 27. Summary of GYRITS Priority Market Packages

Critical Program Areas / Market Packages	Traveler Safety and Security	Emergency Services	Tourism and Travel Information Services	Public Traveler Services/Public Mobility Services	Commercial Vehicle Operations	Infrastructure Operations and Maintenance	Fleet Operations and Maintenance
INCLEMENT WEATHER CHALLENGE							
Broadcast Traveler Information			√			√	
Interactive Traveler Information			√				
Network Surveillance	√					√	
Probe Surveillance						√	
Safe Speed Advisory	√				√		
Traffic Information Dissemination	√		√			√	
UNSAFE SPEED CHALLENGE							
Dynamic Warning System	√						
Mobile Traffic Management/Enforcement	√						
Safe Speed Advisory	√				√		
Traction Control	√						
COMMERCIAL VEHICLE SAFETY CHALLENGE							
CVO Fleet Maintenance					√		√
Driver Safety Monitoring	√				√		√
Mobile Traffic Management/Enforcement	√						
On-board CVO Safety					√		√
Roadside CVO Safety					√	√	√
Weigh-in-motion					√	√	
HAZARDOUS MATERIALS CHALLENGE							
HAZMAT Management					√	√	√
Incident Management System	√					√	
Mobile Traffic Management/Enforcement	√						
EMERGENCY RESPONSE TIME CHALLENGE							
Emergency Response	√	√					
Emergency Routing		√					
Incident Management System	√					√	

Table 27. Summary of GYRITS Priority Market Packages (Continued)

Critical Program Areas / Market Packages	Traveler Safety and Security	Emergency Services	Tourism and Travel Information Services	Public Traveler Services/Public Mobility Services	Commercial Vehicle Operations	Infrastructure Operations and Maintenance	Fleet Operations and Maintenance
EMERGENCY RESPONSE TIME CHALLENGE (Continued)							
Mayday Support	√	√					
Virtual TMC		√				√	
TRAVELER/TOURIST INFORMATION CHALLENGE							
Broadcast Traveler Information			√			√	
Interactive Traveler Information			√				
Network Surveillance	√					√	
Probe Surveillance						√	
Virtual TMC		√				√	
Yellow Pages and Reservation			√				
FAILURE TO YIELD RIGHT-OF-WAY/DISREGARD FOR TRAFFIC CONTROL CHALLENGE							
Intersection Collision Avoidance	√						
Mobile Traffic Management/Enforcement	√						
REAR-END COLLISION CHALLENGE							
Driver Visibility Improvement	√				√		
Intersection Collision Avoidance	√						
Intersection Safety Warning	√						
Pre-Crash Restraint Deployment	√						
ANIMAL ENCROACHMENT ON THE ROADWAY CHALLENGE							
Animal-vehicle Collision Countermeasures	√						
Lateral Safety Warning	√				√		
Longitudinal Safety Warning	√				√		
SNOWMOBILE CRASH CHALLENGE							
Dynamic Warning System	√						
Intersection Collision Avoidance	√						
Lateral Safety Warning	√				√		
Longitudinal Safety Warning	√				√		

Table 27. Summary of GYRITS Priority Market Packages (Continued)

Critical Program Areas / Market Packages	Traveler Safety and Security	Emergency Services	Tourism and Travel Information Services	Public Traveler Services/Public Mobility Services	Commercial Vehicle Operations	Infrastructure Operations and Maintenance	Fleet Operations and Maintenance
COMMERCIAL VEHICLE EFFICIENCY CHALLENGE							
CVO Fleet Maintenance					√		√
Electronic Clearance					√	√	√
Electronic Clearance Enrollment	√				√		√
Fleet Administration					√		√
Freight Administration					√		√
Vehicle Tracking and Dispatch					√		√
Weigh-in-motion					√	√	
TRAVELER MOBILITY CHALLENGE							
Demand Responsive Transit Operations				√			
Dynamic Ridesharing			√	√			
Multimodal Coordination							√
Traffic Infomation Dissemination	√		√			√	
Transit Fixed-Route Operations				√			√
Transit Passenger and Fare Management				√			√
Transit Vehicle Tracking							√
Vehicle Tracking and Dispatch							√
YELLOWSTONE NATIONAL PARK ENTRANCE CONGESTION CHALLENGE							
Facility Use/ Parking Fee Management			√				
Mobile Traffic Management/Enforcement	√						
Traffic Information Dissemination	√		√			√	
Transit Fixed-Route Operations							√
CONSTRUCTION ZONE CONGESTION CHALLENGE							
Mobile Traffic Management/Enforcement	√						
Traffic Information Dissemination	√		√			√	
TOURISM AND ECONOMIC DEVELOPMENT CHALLENGE							
Facility Use/ Parking Fee Management			√				
Transit Passenger and Fare Management							√

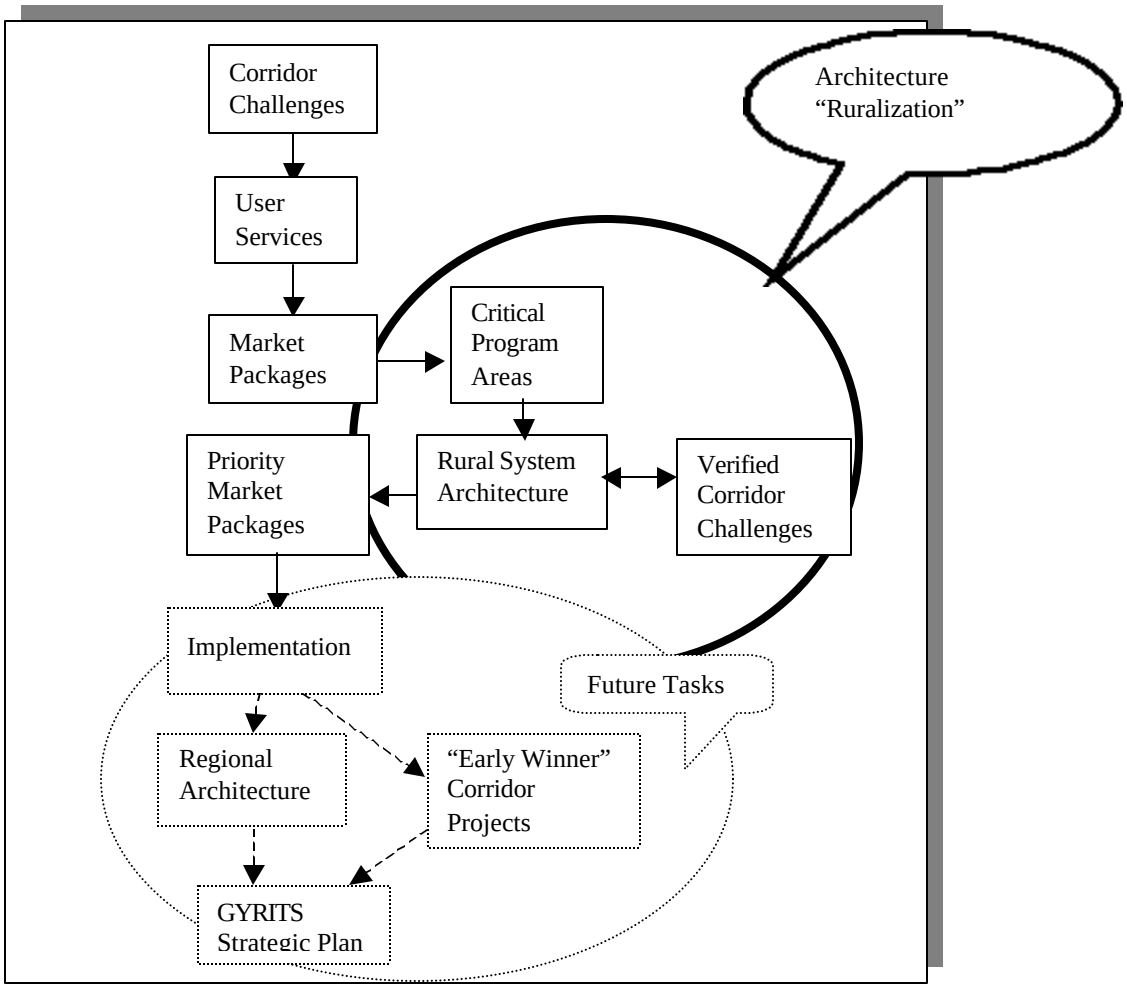

Figure 4. Next Steps

anticipated quantitative and qualitative benefits. While architecture issues are important, the GYRITS Steering Committee may ultimately select which project(s) to deploy. Following deployment, "after" conditions can be recorded to quantify the benefits of ITS. It is anticipated that deployment will occur in the summer of 1998.

Task 10: Preliminary Project Deployment

The goal of Task 10 is to deploy the systems identified in Task 9. More specifically, this task includes steps necessary to prepare pre-construction documents, provide deployment coordination, and identify local matching funds.

Project efforts will be coordinated and documented by WTI to ensure success and so that participating agency efforts may be used for local match toward federal cost share funding arrangements. The early winner project will attempt to add value to already on-going initiatives.

Tasks 11, 12, and 13: Define Regional Architecture, Develop ITS Systems Architecture and Operations Report, and Evaluate Systems and Produce Final Report

The definition of the GYRITS Corridor Regional Architecture, an identification of "early winner" projects, the development of implementation strategies and the quantification of system benefits will be the primary products resulting from Tasks 11, 12, and 13. The GYRITS Corridor Regional Architecture will rely on phased deployment to maximize value-added implementation scenarios. The documentation of the operations and evaluation of the "early winner" projects will be included in a final report.

Communications requirements for each of the project technologies may need to be investigated further to determine range, signal, and transmission requirements. The communication requirements of the rural market packages can be obtained by reviewing the parent market packages in National System Architecture documents as necessary. Due to the dynamic nature of the communications industry, several communication media have recently become cost-effective. Improvements in current levels of service and reliability for many of the technologies discussed may become reality in the near future. For example, cellular coverage in the GYRITS Corridor may allow for future use of this technology in locations where it is not now feasible.

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