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WSDOT Intermodal Data Linkages Freight ITS Operational Test Evaluation

Final Report

Part 1: Electronic Container Seals Evaluation

U.S. Department of Transportation

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16. Abstract

In mid-1999, in response to the U.S. Department of Transportation's (USDOT) request for participation in the Intelligent Transportation Systems (ITS) Intermodal Freight Field Operational Test (FOT) Program, the Washington State Department of Transportation (WSDOT) entered into a partnership with public and private organizations to test and evaluate ITS solutions for an "Intermodal Data Linkages ITS Operational Test". As the main element of this test, electronic intermodal container seals (E-seals) were tested and evaluated in two scenarios: (1) to support U.S. Department of Agriculture (USDA) operations concerning in-bond shipments of containerized produce shipments being moved by truck from the Port of Tacoma across the international border into British Colombia, and (2) to support U.S. Customs (USCS) operations in tracking in-bond auto parts shipments via container ships from Japan to the Port of Tacoma, and then being moved by truck from the Port of Tacoma across the international border into British Colombia. SAIC served as the "Independent Evaluator" for this deployment. This report presents a discussion of the SAIC Evaluation Team findings from the deployment experience. The results of this evaluation, along with corresponding conclusions and recommendations, are detailed in this report. Several key conclusions are summarized as follows:

- The concept of a disposable, low-cost E-Seal technology was confirmed. Considering the system was the first prototype E-seal system tested in an operational environment within the United States, the system performed well. The test validated the E-seal operational concept across two different intermodal freight supply chains.

- Technology challenges early in the test were successfully overcome. As the FOT began, the original E-seal design faced challenges with broadcast speed being too slow to read moving trucks. Through cooperative efforts between the system integrator and the E-seal vendor, the system was successfully re-engineered to broadcast at a sufficiently increased rate to

support roadway speed conditions.

- The flexibility exhibited by the stakeholders was key to the test's success. USDA and Maersk Sealand modified the initial procedures early in the test to accommodate initial operational problems. Additionally, Westwood Shipping undertook several activities to shield its customers from any disruptions and worked with a new motor carrier (as did USDA and Maersk Sealand) to ensure the test would occur within the time constraints.

This report is Part 1 of two reports. A second volume of this report entitled, "Part 2: Freight ITS Traffic Data Evaluations," is being published separately. Part 2 covers two additional projects evaluated as part of the WSDOT Intermodal Data Linkages FOT; however these two projects are not technically related to or integrated with the E-Seal deployment.

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ABBREVIATIONS

ACE	Automated Commercial Environment
ACS	Automated Container System
AVI	Automated Vehicle Identification
CCRA	Customs Container Release Authorization
CHCP	Cargo Handling Cooperative Program
COTR	Contracting Officers Technical Representative
CVISN	Commercial Vehicle Information Systems and Networks
DoD	Department of Defense
DOT	U.S. Department of Transportation
DSRC	Dedicated Short Range Communications
EB	Eastbound
E-seal	Electronic Seal
FCC	Federal Communications Commission
FHWA	Federal Highway Administration
FOT	Field Operational Test
GAO	Government Accounting Office
ID	Identification
INS	Immigration & Naturalization Service
ISP	Internet service provider
ITI	Intelligent Transportation Infrastructure
ITS	Intelligent Transportation Systems
JIT	Just-in-Time
JPO	Joint Program Office
MARAD	Maritime Administration
MOE	Measure of Effectiveness
MOP	Measure of Performance
MPOs	Metropolitan Planning Organizations
NB	Northbound
NORPASS	North American Preclearance and Safety System
SAIC	Science Applications International Corporation
SB	Southbound
TCOS	Trade Corridor Operations System
USCS	U.S. Customs
USDA	U.S. Department of Agriculture
USDOT	U.S. Department of Transportation
WA	Washington
WB	Westbound

WIM	Weigh-in-Motion
WMD	Weapons of Mass Destruction
WSDOT	Washington State Department of Transportation

EXECUTIVE SUMMARY

FOREWORD

This report presents the independent evaluation findings of the U.S. Department of Transportation (USDOT)-sponsored Operational Test of an electronic container seal (E-seal) prototype system conducted in Washington State and British Columbia, with supply chain links to Asia. This test represents a 2.5-year effort to deploy a new intermodal freight technology in a complex operational and institutional environment. The successes in this test are largely due to the significant and persistent institutional cooperation in this deployment – the project managers (Washington State Department of Transportation [WSDOT]); the U.S. Customs Service (USCS); the system integrator; the E-seal vendor; the Port of Tacoma and the Port of Seattle; two trucking companies; and the U.S. Department of Agriculture (USDA). These entities, and others, have worked together to overcome several major hurdles to make this project a success.

However, a new context has overshadowed this effort. The tragic events of September 11, 2001 have set in motion a new focus on intermodal freight security within our government and our industries. There are significant renewed concerns about the security of intermodal containers, particularly with regard to their potential use as a means to smuggle in weapons of mass destruction.

The USDOT and the USCS are working together with industry to respond to these concerns by looking at the role that technology can play in promoting container security. This Operational Test has provided a significant starting point for this dialogue. Currently, by building upon the groundwork that USDOT laid with this field operational test (FOT), the USCS is deploying the same E-seal developed here in a new operational test in partnership with Canadian Customs. It is anticipated that this new test could pave the way for an automated E-seal clearance system for “trusted shippers” to be investigated by USCS soon.

This test has also helped to lay the foundation for potential new tests of E-seal technologies. These new tests may include a follow-on test of new E-seal technologies in Washington State, as well as a yet undefined series of potential E-seal demonstration efforts under the Operation Safe Commerce Program, the Safe and Secure Trade Lanes Program, with oversight from the USDOT Office of Intermodalism and the Maritime Administration (MARAD) Cargo Handling Cooperative Program (CHCP). Additionally, this test is providing a major “lessons-learned” input to the current E-seal architecture development effort being led by the Applied Physics Lab (APL) at John Hopkins University, under the guidance of the Federal Highway Administration (FHWA) Office of Freight Management and Operations.

Background

In mid-1999, USDOT issued a request for participation in the Intelligent Transportation Systems (ITS) Intermodal Freight Field Operational Test Program. In response, WSDOT entered into a partnership with public and private organizations to test an operational prototype system to track intermodal cargo containers with disposable electronic seals (E-seals). Disposable E-seals were chosen for this test due to their potentially low cost in mass production versus permanent electronic seals. TransCore

was chosen by WSDOT as the system integrator for this FOT to oversee and integrate the various technologies associated with the E-seal system.

The e-Logicity/E. J. Brooks prototype E-seal system was selected by WSDOT and TransCore as the candidate disposable E-seal system to be tested in this FOT. The primary goal of this system is to validate the audit trail for seal status through the supply chain of a container shipment. This validation process includes determining the integrity of the E-seal and recording the time and place of each seal each transaction (i.e., each location where the E-seal was “read” by a device). This is accomplished remotely by reader antennas or by humans with hand-held readers in a fashion similar to the manual seal validation process. Figure ES-1shows components of the e-Logicity/E. J. Brooks prototype E-seal used in this FOT.

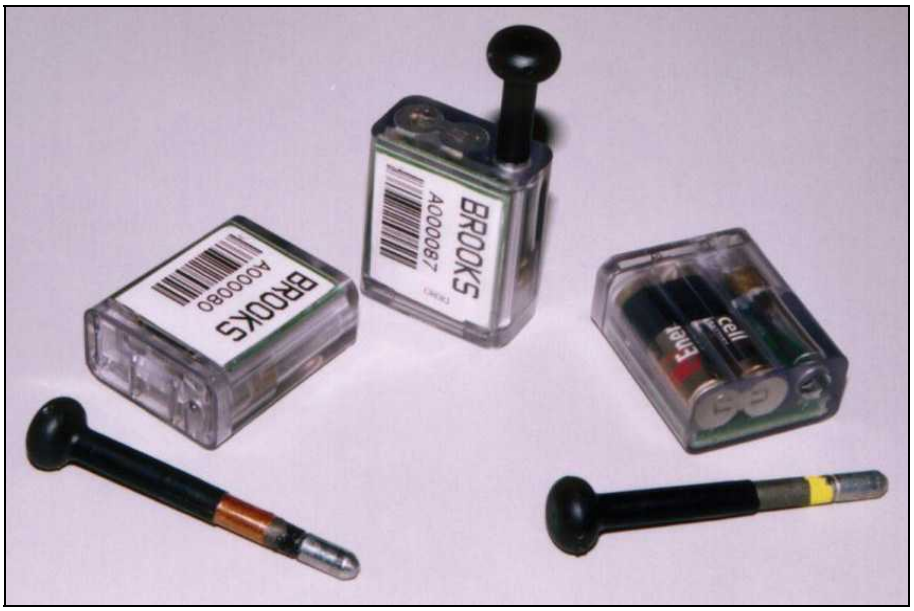


Figure ES-1. e-Logicity/E. J. Brooks Prototype E-Seal.

Prior to initiating this E-seal FOT, USCS and USDA had identified their in-bond load tacking capabilities as inadequate. Current USDA and USCS systems require up to 30 days to confirm that in-bond loads have exited the U.S. It was anticipated that the use of E-seal technology would facilitate border clearance activities and commercial vehicle enforcement, and streamline operations for both regulatory agencies and private sector transportation companies.

Additionally, the intermodal freight industry in the Seattle region has a major interest in experimenting new technologies, such as E-seals, which have the potential to provide their operations with improved efficiencies. Maersk Sealand, a steamship line with a major terminal at the Port of Tacoma, has been a committed private sector participant since this project began, and participated in one of the two major supply chain tests of

E-seals for this FOT. Westwood Shipping[1], a steamship line with a major terminal at the Port of Seattle, participated in the other major supply chain test for this FOT. As presented in Table ES-1, WSDOT, TransCore, USCS, USDA, Maersk Sealand, and Westwood Shipping were supported in conducting this test by a number of other significant public and private partners.

Table ES-1. E-Seal System Test Participants

PARTNER	ROLE						
	Project Management	System Development	System Deployment	Participant Recruitment/ Outreach	System Participant	Evaluation	Project Oversight
Public Sector Partners:							
USDOT							●
WSDOT/TRAC	●	●	●	●			
Port of Tacoma		●		●			
Port of Seattle		●		●			
USDA					●		
USCS		●			●		
Private Sector Partners:							
APL/Eagle Marine Terminal		●		●	●		
Maersk Sealand					●		
Westwood Shipping Lines					●		
TransCore		●	●		●		
e-Logicity		●	●				
PRTI (trucking company)					●		

[1] A subsidiary of American Presidents Line (APL; its terminal at the Port of Seattle is operated by Eagle Marine Services, which is also a subsidiary of APL.

PARTNER	ROLE						
	Project Management	System Development	System Deployment	Participant Recruitment/ Outreach	System Participant	Evaluation	Project Oversight
Shadow Lines (trucking company)					•		
SAIC						•	
Cambridge Systematics						•	

An Evaluation Team led by Science Applications International Corporation (SAIC) was selected in January 2000 to develop and implement an evaluation of this WSDOT Intermodal Data Linkages FOT under the direction of the USDOT ITS Joint Program Office (JPO). The objective of this evaluation was to identify goals and "lessons learned" with respect to implementing intermodal ITS technologies to the intermodal freight industry, other states, regions, and Metropolitan Planning Organizations (MPOs) contemplating the implementation of similar technologies. The evaluation focused on the following four areas:

- Intermodal Freight System Operations
- Technology Applications
- Institutional Challenges
- Participant Satisfaction

System Test Overview

Some system elements that supported this E-seal test were deployed as far back as 1998, when containers moving from the Ports of Seattle and Tacoma were tracked using vehicle transponders and Automated Vehicle Identification (AVI) readers along I-5. The "TransCorridor" system developed by TransCore was the backbone of this test. TransCorridor is a freight-tracking Internet-based information system that is augmented by a regional deployment on both sides of the border that includes Commercial Vehicle Intelligent Systems Network (CVISN) AVI readers and weigh-in-motion (WIM) sensors. For this test, however, only AVI reads from the Bow Hill CVISN-equipped weigh station were made available.

The complete deployment history of the E-seal FOT is summarized in Table ES-2. Substantial development efforts were required, including development of electronic seal technology and applicable hardware and software components, and the integration of these components into the TransCorridor system. E-seal deployment began during the second year of the project.

- USDA/Maersk Sealand successfully deployed the first test group of 47 E-seals on in-bond agricultural shipments moving from the Port of Tacoma to the U.S./ Canadian border. Seals in this test group were in place for a 6-month period between December 2001 and June 2002, and were still in use during the preparation of this report.

- USCS/Westwood Shipping successfully installed the second test group of 30 E-seals on in-bond auto part shipments moving from Japan through the Port of Seattle to the U.S./Canadian border. Seals in this test group were in place for approximately 6 weeks from May to June 2002.

- TransCore and Shadow Lines successfully deployed an E-seal on a transponder-equipped truck for one load as a proof-of-concept.

Table ES-2. Deployment Activities Timeline for the E-Seal Test

DEPLOYMENT ACTIVITIES	PERIOD OF TIME			
	1998	1999	12/01 to 6/02	5/02 to 6/02
• Initial test conducted using vehicle transponders and AVI readers along I-5 using TransCore's TransCorridor system.	•			
• Disposable E-seal system development; ongoing recruitment of test participants.		•	•	•
• Conducted E-seal Test A deployment for USDA/Maersk Sealand using 47 E-seals during 6-month period; E-seals currently in use.			•	
• Conducted E-seal Test B deployment for USCS/Westwood Shipping Lines using 30 E-seals during 6-week period.				•

Evaluation Analysis and Results

The analysis of the ability of the TransCorridor/e-Logicity system to be able to effectively read E-seals in an operational environment was key to validating the E-seal operational concept. A summary of the results of this analysis is presented in Figure ES-2.

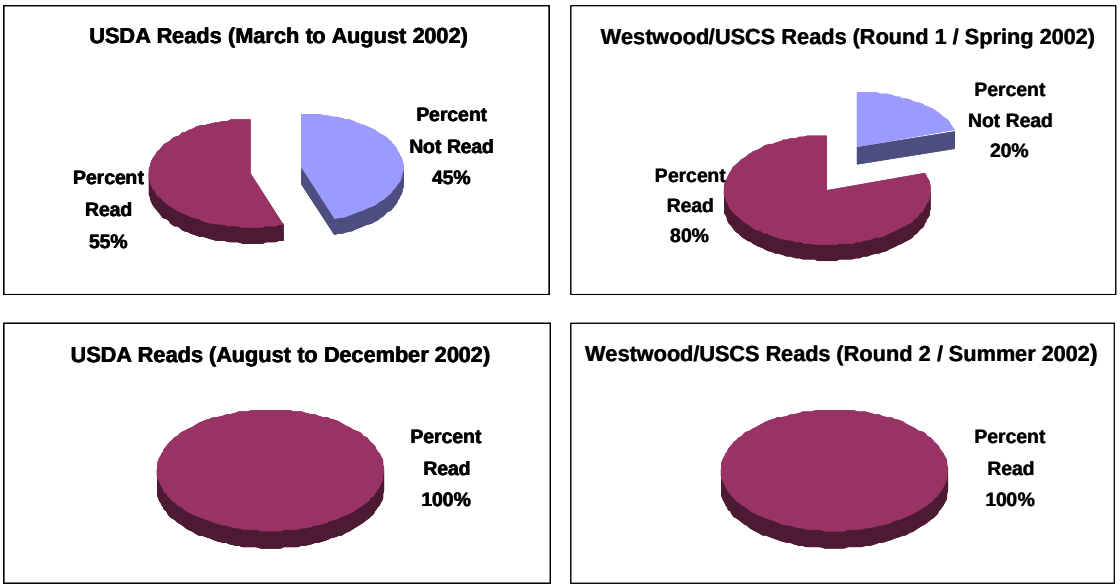


Figure ES-2. E-Seal Read Results.

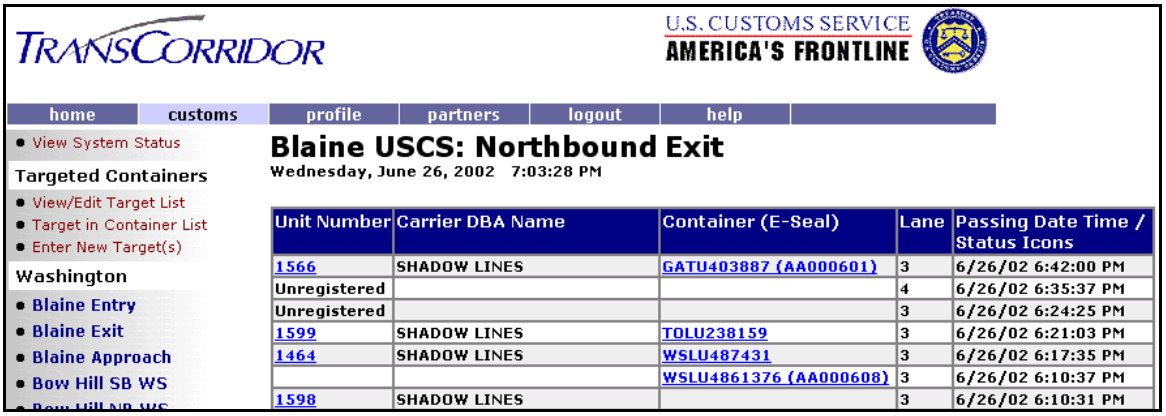
As shown in Figure ES-2, the first phase of the USDA/Maersk Sealand test occurred between March and early August 2002, and consisted of installing 47 E-seals (two or less per week). The TransCorridor data showed a read rate for these E-seals at 55 percent, with 26 out of 47 E-seals being successfully read. A number of operational issues, including inadequate system training and truck drivers using the wrong border crossing at Blaine, were responsible for this initially low read rate. However, these operational issues were corrected in the second portion of this test, which took place between August and December 2002. During the second test, 12 of 12 E-sealed containers (100 percent) were successfully read by USDA inspectors. This test effectively validated the success of the Transcore/e-Logicity system as applied to the Maersk Sealand /USDA E-seal supply chain.

As shown in Figure ES-2, during the spring of 2002, Westwood installed 30 E-seals in Japan as part of the initial portion of this test ("Round 1"). All 30 E-seals were inspected and read using hand-held readers by USCS officers at the Port of Seattle. Three E-seals registered as "tampered" during the read process. Of the 30 E-seals installed, 20 percent (or six) were not read at the Blaine border crossing. Participants believe read failures were due to a malfunctioning fixed reader at the border and not the actual seal. This problem was corrected in the second portion ("Round 2") of the USCS/Westwood test, which took place over the summer of 2003. During the second test, 28 of 28 E-sealed containers (100 percent) were successfully read at the Blaine

USCS station. This test effectively validated the success of the Transcore/e-Logicity system as applied to the USCS/Westwood E-seal supply chain.

The potential value of this technology was also demonstrated when a truck disappeared. When the truck was not detected at the border crossing, the USDA was alerted and was able to react in less than half the time normally taken under the traditional system. Both the driver and load were still missing as of October 2002, and an ongoing investigation is being conducted. It is expected that the E-seal system will assist with prosecution when the driver is apprehended.

During this FOT, Transcore also conducted a proof-of-concept demonstration to show that e-Logicity E-seal reads could be associated with TransCorridor AVI system reads in an operational environment. Here, a Shadow Lines truck equipped with an AVI transponder was married with a container that was affixed with an E-Seal, and sent through the Blaine border crossing northbound approach. On June 26, 2002 at 6:42:00 p.m., a single Shadow Lines vehicle (Unit # 1566 – Tag #20876BC1) passed through the Blaine Northbound Exit and successfully demonstrated that the system correlated the vehicle to a container (GATU403887) with an attached E-seal (AA000601). Depicted in Figure ES-3, the E-seal was detected at the Blaine Exit, and all vehicle, container, and E-seal information were correctly displayed on the TransCorridor Website.



Unit Number	Carrier DBA Name	Container (E-Seal)	Lane	Passing Date Time / Status Icons
1566	SHADOW LINES	GATU403887 (AA000601)	3	6/26/02 6:42:00 PM
Unregistered			4	6/26/02 6:35:37 PM
Unregistered			3	6/26/02 6:24:25 PM
1599	SHADOW LINES	TOLU238159	3	6/26/02 6:21:03 PM
1464	SHADOW LINES	WSLU487431	3	6/26/02 6:17:35 PM
		WSLU4861376 (AA000608)	3	6/26/02 6:10:37 PM
1598	SHADOW LINES		3	6/26/02 6:10:31 PM

Figure ES-3. TransCore/Shadow Lines Test Information Displayed on the TransCorridor Website.

The technical effectiveness evaluation investigated the ability of the system tested to perform the functions described in the Northwest International Trade Corridor Program Functional Specification. As described in this document, the system must: positively identify the vehicle and container; reliably associate an E-Seal container read with a truck AVI read; and have a low failure rate. The system should have the capability to detect tags; correlate container number and vehicle number; record the vehicle number, container number, and departure time in the database; and perform other required data processing. The findings of this evaluation concluded that the functional requirements of the original system design were either met or exceeded during the FOT system operations.

Conclusions

Table ES-3 presents a summary of a number of the major conclusions developed as part of this evaluation. These conclusions are based on the deployments and the evaluation data collection analysis and results, as well as looking at the national impacts this FOT could have on the ongoing freight security initiatives.

Table ES-3. Summary of Conclusions

Category	Conclusions
System Operations	• **System Performance was Acceptable and Validated the E-Seal Concept.** Considering the system was the first prototype E-seal system tested in an operational environment within the United States, the system performed well. While the initial E-seal read rates were only adequate in the early months of the test, during the latter months, the system had approached a near 100 percent read rate, thus validating the E-seal operational concept. • **The Infrastructure Will Need Upgrading to Support a Deployed System.** While this test developed and deployed a system with all the necessary components, it is not a complete infrastructure that could support fully deployed operations. For example, there are no stationary readers at the port gates or along I-5 between the Seattle/Tacoma region and the border that could support government security and industry efficiency-tracking requirements.
Technology	• **Technology Challenges Early in the Test Were Successfully Overcome.** As the FOT began, the original E-seal design faced challenges with broadcast speed being too slow to read moving trucks. Through cooperative efforts between the system integrator and the E-seal vendor, the system was successfully re-engineered to broadcast at a sufficiently increased rate to support roadway speed conditions. • **The Concept of a Low-Cost Disposable E-Seal Technology Was Confirmed.** The e-Logicity E-seal, which is now being manufactured and marketed by E.J. Brooks, proved the technology concept that a low-cost disposable electronic container seal could be developed. However, some technical challenges must be addressed in the future, including the seal's operating frequency – the E-seal operates with a Department of Defense (DoD) frequency (315 MHz) that will need to be changed under a full deployment scenario. Additionally, neither of the potential operating frequencies of this E-seal (315 MHz and 433.92 MHz) is compatible with CVISN AVI truck transponder technology. • **The Hand-Held E-Seal Reader Technology Will Need Further Development.** The hand-held readers proved difficult to operate due to the user having to navigate through a cumbersome series of menus. Also, the hand-held reader is not able to automatically populate the E-seal number field by obtaining that number from the E-seal itself. Additionally, unit has a short battery life, and there is currently no wireless method available for the reader to upload its data to the TransCorridor system.
Institutional Challenges	• **The Public-Private Partnership for this FOT Performed Admirably.** Over the duration of this FOT, there were considerable institutional, technological, and operational challenges that affected the project

Category	Conclusions
	schedule adversely. WSDOT, supported by USDOT, the Port of Tacoma, and Maersk Sealand showed dogged persistence in resolving these factors. In the end, this resulted in the development and deployment of a successful system, despite a 1-year schedule slip. • **Communication Was Key to the Test's Success.** The regional stakeholders remained interested and supportive of the program over a fairly lengthy deployment process. This ongoing supportive coordination allowed multiple agencies to become more knowledgeable regarding the entire topic of international trade and border-crossing issues. Additionally, operations staff from USDA, USCS, Maersk Sealand, Westwood, and PRTI worked successfully to establish their new operating procedures within the confines of the operational test, while maintaining their own daily business functions.
Stakeholder Participation	• **The Flexibility Exhibited by the Stakeholders was Key to the Test's Success.** USDA and Maersk Sealand modified the initial procedures early in the test to accommodate initial read failures when 12 of the first 14 E-seals coded by the USDA were not read at Blaine. For USCS and Westwood, the flexibility was evident in the steps both entities took to make the test happen. Westwood undertook several activities to shield its customers from any disruptions and worked with a new motor carrier (as did USDA and Maersk Sealand) to ensure the test would occur within the time constraints. • **Deployment Occurred With Minimal Impact to the Industry Partner's Customers.** It was critical to the freight industry participants testing this system that their willingness to participate not result in any disruption to their customers. In an effort to minimize interactions with customers, Westwood provided an agent to install the E-seals in the Japan port and instructed its truck drivers to cut off the E-seals after exiting the United States.
Security	• **Events of 9-11 Caused a New Focus on Security During the Last Year of this FOT.** E-seals are being reviewed by the Cargo Handling Cooperative Program (CHCP) as perhaps the central in-the-field detection element in a future intermodal freight security system. Results of this test, while not focused in any major way on security, do provide input to ongoing research and discussions of the federal government, CHCP, and others, who are considering various E-seal technology options and architectures. Results of this evaluation will provide input for a current project at the Applied Physics Laboratory at John Hopkins University to develop an "E-seal architecture" for USDOT. • **The U.S. Customs Service is Examining the Deployment of This Technology.** Cargo security has now become a major focus for the USCS, which now has plans to build on the USDOT-sponsored system with expansion into Canada for in-bond shipments to the United States. This expansion may include operations in Vancouver, Montreal, and Halifax. Additionally, a system using "trusted shippers" is currently being examined by USCS, and with USCS support, this opportunity could materialize into a system that could incorporate E-seals. • **An E-Seal System Cannot Fulfill Security Requirements on its Own.** A major concern with the disposable E-seal technology tested here is that the information is not real-time. While this system may help to reduce acts of pilferage on containers by being able to track later when the container was opened, it does nothing to stop the potential corruption of a container

Category	Conclusions
	with weapons of mass destruction (WMD) during shipment. However, if E-seals are just one point of security data in an overall intermodal freight security system, then this data can be integrated with other system data to provide for enhanced security against worst-case scenarios such as WMD smuggling. Such systems are currently being examined in the Federal Motor Carrier Safety Administration's (FMCSA) Hazardous Material Transportation Safety and Security National Operational Test.

Recommendations

Following is a selection of some the key recommendations that the Evaluation Team is offering to USDOT, WSDOT, the project stakeholders, and others in government and industry based on the conclusions obtained in conducting this evaluation.

- The number of participants should be expanded in future applications of this and other E-seal technologies to test the system with a larger volume of entries – just over 100 E-seals were coded and put through this system. A larger number of E-seals should be tested with more industry participants and with a more comprehensive set of supply chains to validate the statistical significance of these initial findings.

- In moving forward with this next phase of this E-Seal system, the infrastructure should be further developed to include additional E-seal fixed readers and/or antennas on all exit lanes and the bypass lane, or a link to the existing AVI/ transponder system. Most participants commented that full deployment is the only way to really quantify the benefits.

- The e-Logicity/Brooks E-seal should be re-engineered to work on an accepted frequency. The possibility of developing an E-seal which could operate using the existing CVISN/AVI truck transponder frequency and infrastructure should be examined.

- The e-Logicity/Brooks hand-held E-seal readers should be re-engineered to improve their functionality; automatically populate the E-seal number field; significantly improve battery life; and allow for wireless uploading to the TransCorridor System.

- A national border enforcement procedure should be defined and developed to address any E-sealed loads that appear to be "tampered with" upon reaching a USCS border entry station into Canada or Mexico. This is an important component, because in this test, within a mile of passing the fixed reader, the truck enters Canada, thereby leaving United States' jurisdiction.

- There should be concern on the over the potential reliance of a single system such as an E-seal system that has no duplication for secondary security checks, and is not part of an integrated security system. With this in mind, any technology that is implemented to increase security will have to be fully supported and work with other

systems to ensure that the integrity of shipments must be verified through multiple checks.

- It will be critical in coming years for the USDOT, U.S. Department of Homeland Security, USCS, CHCP, IFTWG, private industry, state DOTs, and others to work together to integrate currently disparate government systems such as ACE, FAST, ITDS, CVISN, etc., to support common needs for improved national security and improved industry efficiency though intermodal freight technologies.

1. INTRODUCTION

In mid-1999, the U.S. Department of Transportation (USDOT) awarded funding for an Intermodal ITS Field Operational Test (FOT) to a regional consortium led by the Washington State Department of Transportation (WSDOT). The primary focus of this "WSDOT Intermodal Data Linkages FOT" was to demonstrate the use of electronic seals (E-seals) on containers to track movements and monitor the security of containerized freight moving in-bond through the United States.

This FOT was developed in response to a need by U.S. Customs (USCS) to improve its ability to track in-bond shipments. The existing system does not provide adequate security for shippers, who have up to 30 days to inform USCS the load has cleared the United States. The test was also expanded to include the U.S. Department of Agriculture (USDA), which faces similar issues for the in-bond movement of specific agriculture and food products.

As a secondary benefit, it was anticipated that using E-seal technology would facilitate border clearance activities and streamline operations for the regulatory agencies and the private sector transportation companies. This test required participants ranging from motor carriers, to steamship lines, to system developers, to regulatory agencies.

In support of the USDOT's Intermodal Freight Intelligent Transportation Systems (ITS) Program, an Evaluation Team led by Science Applications International Corporation (SAIC), under the direction of the USDOT Joint Program Office (JPO), was selected in January 2000 to develop and implement an evaluation of this FOT. The ultimate goal of this evaluation is to identify "lessons learned" with respect to implementing intermodal ITS technologies involving the tracking of intermodal cargo containers with disposable electronic seals.

In conducting the independent evaluation of this FOT, the Evaluation Team focused on the following four study areas:

- Identify improvements in ***Intermodal Freight System Operations*** resulting from ITS technologies;
- Assess the ***Technical Effectiveness*** of the technology applications in fulfilling their stated functions;
- Assess the ***Customer Satisfaction*** expressed by key information users; and
- Identify the key ***Institutional Challenges*** encountered in establishing partnerships and sharing information among public agencies and private businesses.

The evaluation technical approach for each of the tests was similar. Each test was based on the development of an evaluation plan and a series of detailed test plans for each evaluation study area that were developed early in the test. Each evaluation element consisted of data collection efforts that focused on available system data and statistical reporting; data that was provided manually by participants; and finally, the perception data collected through several interviews with participants. These data were

then used to analyze the deployments from several perspectives, including operational impact, institutional challenges, customer satisfaction, and technical effectiveness. Based on these analyses, subsequent findings, conclusions, and recommendations were developed.

It is anticipated that the "lessons learned" from these assessments will provide guidance to the USDOT, the USCS, the intermodal freight industry, and others who are contemplating implementing similar technologies, especially given the recent national focus on improving intermodal freight security.

The succeeding portions of this draft final report document are organized as follows:

- **Section 2. Deployment Overview**. This section provides a comprehensive overview of this FOT, including a description of the stakeholders, the technologies deployed, and the system operational environment.

- **Section 3. Technical Approach**. This section provides a brief description of the evaluation methodology and then presents the Evaluation Team's detailed process mapping activity for each supply chain test.

- **Section 4. Data Analysis and Results**. This section presents a summary of the detailed analysis and results that were developed by the Evaluation Team for the following three areas: (1) Analysis of E-seal System Operational Performance; (2) Summary of Participant Satisfaction and Identified Institutional Challenges; (3) Analysis of the Technical Effectiveness of the System.

- **Section 5. Conclusions and Recommendations**. This section provides the Evaluation Team's conclusions and recommendations developed from conducting this 2.5-year evaluation effort. The conclusions are organized across the following five categories: system operations, technology, institutional challenges, stakeholder participation, and security.

This final report document was developed by the SAIC Independent Evaluation Team, which includes Science Applications International Corporation (SAIC) and Cambridge Systematics (CIS).

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2. DEPLOYMENT OVERVIEW

2.1 FOT OVERVIEW

In the intermodal freight world, electronic container tags are often discussed as a potentially valuable tool for monitoring and tracking containers. Global electronic container tagging, however, has not occurred for several reasons. One reason is that the number of containers in circulation (over 15 million) makes system-wide tagging costly. Effective use of this procedure would require all containers to be tagged. Since container pools are shared and routing patterns are so diversified, there is no guarantee that a given container will be available for a specific trade corridor. In response to this situation, this FOT has taken the unique approach of testing disposable E-seals, instead of the more expensive permanent container tags.

The primary goal of any first-generation E-seal system should be to validate the audit trail for seal status through the supply chain of a container shipment. This validation process should include determining the integrity of the seal and recording the time and place of each seal each transaction (i.e., each location where the seal was “read” by a device). This can be done either remotely by reader antennas or by humans with hand-held readers in a fashion similar to the manual seal validation process.

Based on the preceding considerations, the E-Logicity/E. J. Brooks prototype E-seal system was selected by WSDOT and TransCore as the candidate system for this FOT. A summary of the characteristics and product information for this E-seal is presented in Figure 2-1. It should be noted that more recent versions of this seal are now being tested under the CHCP E-seal testing program, and are also in use or being considered for use in several other regional tests in the United States and Canada.

The primary objective of this FOT was to improve tracking of in-bond shipments moving through the Ports of Seattle and Tacoma using this E-seal system. A second major objective of this test was to examine the utility of providing regulatory agencies with the ability to determine if a load has been tampered with at key check points and to verify when a shipment cleared the U.S. border.

A number of potential benefits can be anticipated for the freight community and the regulatory agencies responsible for monitoring these shipments. For the freight industry, the objectives were to provide shippers with the ability to better track their shipments across multiple modes, to facilitate their ability to meet the regulatory requirements for shipments of this type, and to increase their ability to track theft and tampering attempts. For the regulatory agencies, the primary objective was to be able to better ensure that in-bond shipments clear the U.S. border in a timely manner without being opened, which will increase their enforcement capabilities and result in increased homeland security. The champions of this FOT believed that better information from the E-seal might persuade the border enforcement agencies to allow trusted carriers to cross the border somewhat unimpeded.

PRODUCT CATEGORY	Active RFID Electronic Seal		
Firms	**EJ Brooks (e-Logicity)** (seal originally developed by e-Logicity)	www.ejbrooks.com E.J. Brooks Company World Headquarters 8 Microlab Road Livingston, NJ 07039	Paul Dietlin or Bob Debrody 973-597-2900 paul.dietlin@ejbrooks.com bob.debrody@ejbrooks.com
Product	**eSeal**		
Electronics	• 315 MHz for Pacific NW test; 433.92 MHz production version also available • Plan to comply with ISO 18185 • Range 50 meters, omnidirectional • Data capacity is 128 bits • Continuous broadcast rate at random 0.5 to 1.0 second intervals at 315 MHz or at random 10 to 12 second intervals at 433.92 MHz. Collision avoidance comes from (1) random selection of broadcast times and (2) sending data packet in triplicate.		
Power	• Single use battery rated at three months		
Physical Protection	• Bolt seal, not re-sealable		
Security Features	• Transmits seal number and tamper status • No random number generation		
Life Cycle	• Disposable		
Market Focus	• Intermodal containers.		
Market Status	• "Early Market." Seals in use for supply chain management and some security applications in selected terminals in US, Europe, Australia, Asia. Completed DOT-funded pilot for in-bond shipments in Pacific NW. Other pilots in implementation phase. Product available for sale.		
Pricing	Seals: ~$25 in lots of 50 ~$25 in lots of 5000 ~$25 in lots of 50000	Fixed readers: ~$ N/A in lots of 10 ~$ N/A in lots of 100	
Comments ❷  	• Product developed as a supply chain management and visibility tool, then applied to security market. • E.J. Brooks has manufactured this seal from the beginning, although it was designed by e-Logicity; E.J. Brooks has recently taken over distribution and marketing of the eSeal from e-Logicity.		

Figure 2-1. E-Seal Overview (updated from FHWA "Wolfe E-Seal Study")[2].

[2] This overview was modified based on new information. Following is the original source for this overview: "Electronic Cargo Seals: Context, Technologies, and Marketplace,", prepared by Michael Wolfe, North River Consulting Group for the USDOT ITS Joint Program Office, July 12, 2002, page M-14.

The desire to better track containers moving from the Ports of Seattle and Tacoma began several years ago with a two-phased test approach. The initial test which began in 1998 involved the use of vehicle transponders and Automated Vehicle Identification (AVI) readers along I-5 from the Ports of Tacoma and Seattle north to the U.S./ Canadian border crossing in Blaine, Washington. The TransCorridor system developed by TransCore was the backbone of this test. The use of this ITS technology was deemed a success. However, for shippers, U.S. Customs (USCS), and U.S. Department of Agriculture (USDA) alike, there was still the serious question of load security as the transponders could neither ensure nor verify that the load was intact – only that the power unit had cleared the border.

The second test consisted of designing and developing the E-seal system. The new system required the development of new disposable electronic seal technology and applicable hardware and software components. These components were also integrated into the TransCorridor system developed by TransCore. This process, which began in 1999, involved substantial development efforts to achieve a successful operational scenario.

In addition, recruitment efforts were ongoing due to market forces and the need to identify multiple private sector participants (a steamship line and motor carrier at a minimum). More than a year after the project began, the first of 47 E-seals were deployed by USDA/Maersk Sealand for a 6-month period between December 2001 and June 2002. The second test group, USCS/Westwood Shipping Lines (Westwood), functioned for approximately 6 weeks from May to June 2002, during which 30 E-seals were deployed. Table 2-1 provides a brief history regarding E-seal deployment activities.

Table 2-1. E-Seal Deployment Activities Timeline

	YEAR			
ACTIVITIES	**1998**	**1999**	**12/01 to 6/02**	**5/02 to 6/02**
• Initial test conducted using vehicle transponders and AVI readers along I-5 using TransCore's TransCorridor system.	•			
• Disposable E-seal system development; ongoing recruitment of test participants.		•	•	•
• Conducted E-seal Test A deployment for USDA/ Maersk Sealand using 47 E-seals during 6-month period.			•	

ACTIVITIES	YEAR			
	1998	1999	12/01 to 6/02	5/02 to 6/02
• Conducted E-seal Test B deployment for USCS/Westwood Shipping Lines using 30 E-seals during 6-week period.				•

For this FOT, 77 E-seals were installed onto containers at two locations – the Port of Tacoma and Japan. For the initial location at the Port of Tacoma, USDA staff installed 47 E-seals on in-bond agricultural shipments being handed by Maersk Sealand. In Japan, a Westwood Shipping Lines (Westwood) agent installed 30 E-seals on containers of auto parts moving in-bond through the Port of Seattle to Canada. This included E-seal inspection and reading by USCS staff upon entry into the United States. Once the loads were sealed, they remained in the test until they cleared the U.S. border in Blaine, Washington. In addition, a one-time trial for testing the ability to link E-seals and a transponder-equipped truck was conducted by TransCore and Shadow Lines.

2.2 FOT PARTICIPANTS AND STAKEHOLDERS

Identifying and bringing all the necessary stakeholders on board for this test was a significant challenge. It was important to have access to regulators, private freight companies, and facilitators, such as the port authorities. The test schedule was impacted by two primary factors. The first factor included the challenges imposed by developing and integrating a new technology. For example, the first E-seal design for this test did not meet the required performance parameters and had to be re-engineered, thereby causing a 6-month delay in the test.

The second factor was the successful recruitment of the right mix of stakeholders. For example, the merger of Maersk and Sealand early in the test period caused a 9-month delay in the test while “Maersk Sealand” resources were focused on the integration of Sealand operations into the former Maersk’s operational and information technology environment. However, of significant benefit to this test, a major new stakeholder, the UDSA, was added mid-way though the test, which allowed for the critical addition of a second supply chain for testing the E-seal system.

The final set of participants provided the opportunity to test the E-seal system in two separate environments with two different supply chains. Following is a list of test participants and their involvement. It is important to note here that the Evaluation Team worked very closely with USDOT and WSDOT, and remained in regular contact with these key participants over the duration of this FOT.

- **USDOT**. USDOT was responsible for national leadership and provided the major share of the funding of this effort. The departments that were involved were the

Office of Intermodalism (part of the U.S. Secretary of Transportation's office), the ITS Joint Program Office, and the FHWA Office of Freight Management and Operations.

- **WSDOT.** WSDOT was the champion of this FOT, providing ongoing leadership, direction, and outreach activities in support of this test. WSDOT was responsible for recruiting, developing, and deploying the system.

- **Port of Tacoma.** The Port of Tacoma was involved as a major player in the design, development, and implementation of the system. The Port also provided key industry insights and access to its customers in support of this deployment.

- **Port of Seattle.** The Port of Seattle was involved as an interested party, providing industry insights and access to its customers in support of this deployment.

- **Maersk Sealand.** Maersk Sealand, a steamship line with a major terminal at the Port of Tacoma, was a committed private sector participant since the project started. Its involvement decreased some when it went through its merger activities, but it was the first participant along with USDA. Maersk Sealand participated in the E-seal supply chain test involving the USDA in-bond container movements from the Port of Tacoma, Washington, to British Colombia, Canada.

- **APL/Eagle Marine Services.** American Presidents Line (APL, a steamship line) and Eagle Marine Services were involved since the project started. Eagle Marine Services (the terminal operator) was responsible for handling Westwood Shipping Lines vessels at the Port of Seattle APL terminal. Eagle Marine Services participated in the supply chain test involving in-bond auto parts container movements from Japan to British Columbia via the Port of Seattle.

- **Westwood Shipping Lines**. Westwood Shipping Lines (a steamship line owned by APL) was the most recent company to join the FOT. Westwood agreed to expand the FOT by providing E-seal installation in Japan to support the supply chain test involving in-bond auto parts container movements from Japan to British Columbia to the Port of Seattle APL/Westwood terminal.

- **Shadow Lines.** A single Shadow Lines transponder-equipped truck was involved in a test with TransCore to test the linking ability of correlating container and E-seal information when read at the Blaine border crossing.

- **PRTI Transport**. PRTI was involved as the trucking company hauling the Maersk Sealand shipments of fresh fruit and vegetables under the USDA supply chain test. PRTI also became involved in supporting the other supply chain test as the trucking company hauling the Westwood Shipping Lines containers of automotive parts.

- **USCS**. The U.S. Customs Service was one of the original champions of this FOT, and was involved from the initial planning stages of this FOT. USCS became an active participant with the joining of Westwood, as they both participated on the "USCS/Westwood" supply chain test involving in-bond auto parts container

movements from Japan to British Columbia via the Port of Seattle APL/Westwood terminal. USCS also has plans to expand and further test E-seal technologies.

- **USDA**. The U.S. Department of Agriculture was not an original participant in this FOT. However, USDA became the first user of the system, along with Maersk Sealand, to improve its tracking ability for in-bond shipments of fresh fruit and vegetables moving via in-bond container shipments through the Port of Tacoma to Canada via truck.

- **e-Logicity**. e-Logicity was responsible for designing and developing the E-seals and readers, and played an integral role in providing the technology and training, as well as the coordination and integration functions with the TransCore system. e-Logicity was recently sold to E.J. Brooks, which now manufactures and markets this E-seal.

- **TransCore**. TransCore was the system engineering contractor for this project, responsible for developing the software, integrating it into its existing program, and deploying many of the field components. Transcore also developed and implemented the "TransCorridor" Website, which provides for Internet-based visibility of the freight tracking and E-seal system.

2.3 SYSTEM TECHNICAL OVERVIEW

The E-seal test included the development and deployment of a new disposable electronic seal system. This system was comprised of electronic container seals; portable hand-held E-seal readers; a stationary E-seal reader located at the U.S. Customs approach at the Blaine commercial vehicle border crossing; and dedicated AVI truck transponder readers[3] at three sites: the Blaine crossing; the Port of Tacoma (at the Maersk Sealand terminal); and the Port of Seattle (at the APL/Westwood Shipping terminal).

"TransCorridor", a freight-tracking information system managed by TransCore, forms the backbone of the system, which is managed from its Trade Corridor Service Center in San Diego, California. This system is augmented by a regional deployment on both sides of the border that includes CVISN AVI readers and weigh-in-motion (WIM)

[3] AVI truck transponder technology is based on the Dedicated Short Range Communications (DSRC) 915 MHz standard. This technology includes in-vehicle transponders that can communicate with roadside or gate system reader antennas. This technology is currently be utilized in a number of trucking applications include supporting state commercial vehicle enforcement under the CVISN (Commercial Vehicle Information Systems and Networks), and a similar system being deployed in Canada. As part of CVISN in the Pacific Northwest, truckers can enroll in the NORPASS transponder program. A truck driver with a NORPASS transponder on his/her truck will be able to utilize automated truck inspection stations bypass lanes that are being deployed throughout the region. In approaching a CVISN-equipped weigh station, the system reads the transponder, and typically sends a "green light" message to the truck, signaling the driver that he/she can proceed through the bypass lane at the weight station. A "red light" message signals the driver that he/she must proceed into the main station lane for inspection. Weigh-in-motion (WIM) systems are typically integrated into these automated stations as well.

sensors; however, for this test, only AVI reads from the Bow Hill CVISN-equipped weigh station were made available.

It is important to note here that the container E-seal reads can be “associated” with the truck cab AVI transponder reads within the TransCorridor system, providing for complete visibility of the truck-container movement through various regional choke points where AVI antennas and or E-seal antennas are located. An overview of this entire set of current and planned AVI, E-seal and CVISN infrastructure is presented in Figure 2-2.

Figure 2-2. Regional E-Seal, AVI, and CVISN Deployed/Planned Infrastructure.

The E-seal system hardware required to implement this test included E-seals (see Figure 2-3), a fixed station gate reader, and some additional hand-held readers. The fixed-station gate reader was installed at the United States approach to the Canadian Border at Blaine. E-seals were affixed in the foreign port of origin and at the Port of Tacoma, and were read upon their departure to Canada at the Blaine Border crossing.

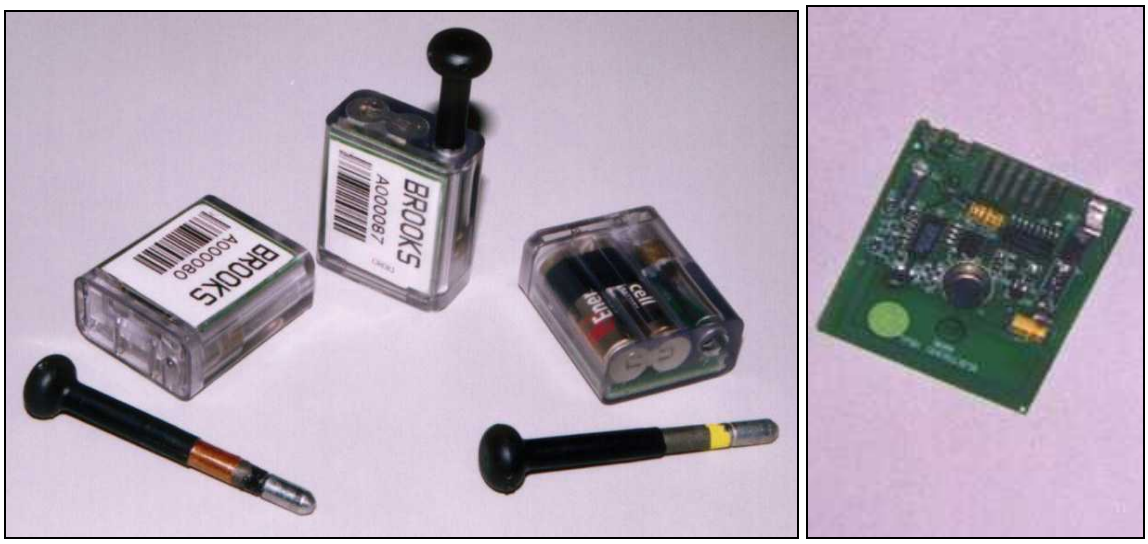


Figure 2-3. Electronic Bolt Seal/Tag Hardware.

For trucks, the E-seal reader was placed in conjunction with truck AVI transponder readers installed at the Blaine U.S. Customs northbound approach. An overview of TransCore's AVI system architecture is presented in Figure 2-4. The E-seal readers and tags were integrated into this system. If both the container seal and a truck tag were read, a container identification (ID) number was associated with a truck ID.

As the truck and container passes under an E-seal antenna and/or an "associated" AVI antenna, the following data can be recorded or verified and communicated over the Internet to the TransCore AVI System[4]:

- Container Seal Number
- Container Number
- Vehicle ID (transponder serial number)
- Date and Time of Entrance Event
- Shipping Facility ID

[4] Note here that the design of the TransCore AVI system and TransCorridor Website also have provisions to allow for the following additional information to be provided by the AVI system in the future: Gate/Lane Number; In-Bond (yes or no); Container Weight; and HAZMAT ID Code. The TransCore AVI system was designed to be interoperable with the Washington State CVISN prototype system deployed at the Bow Hill weigh station.

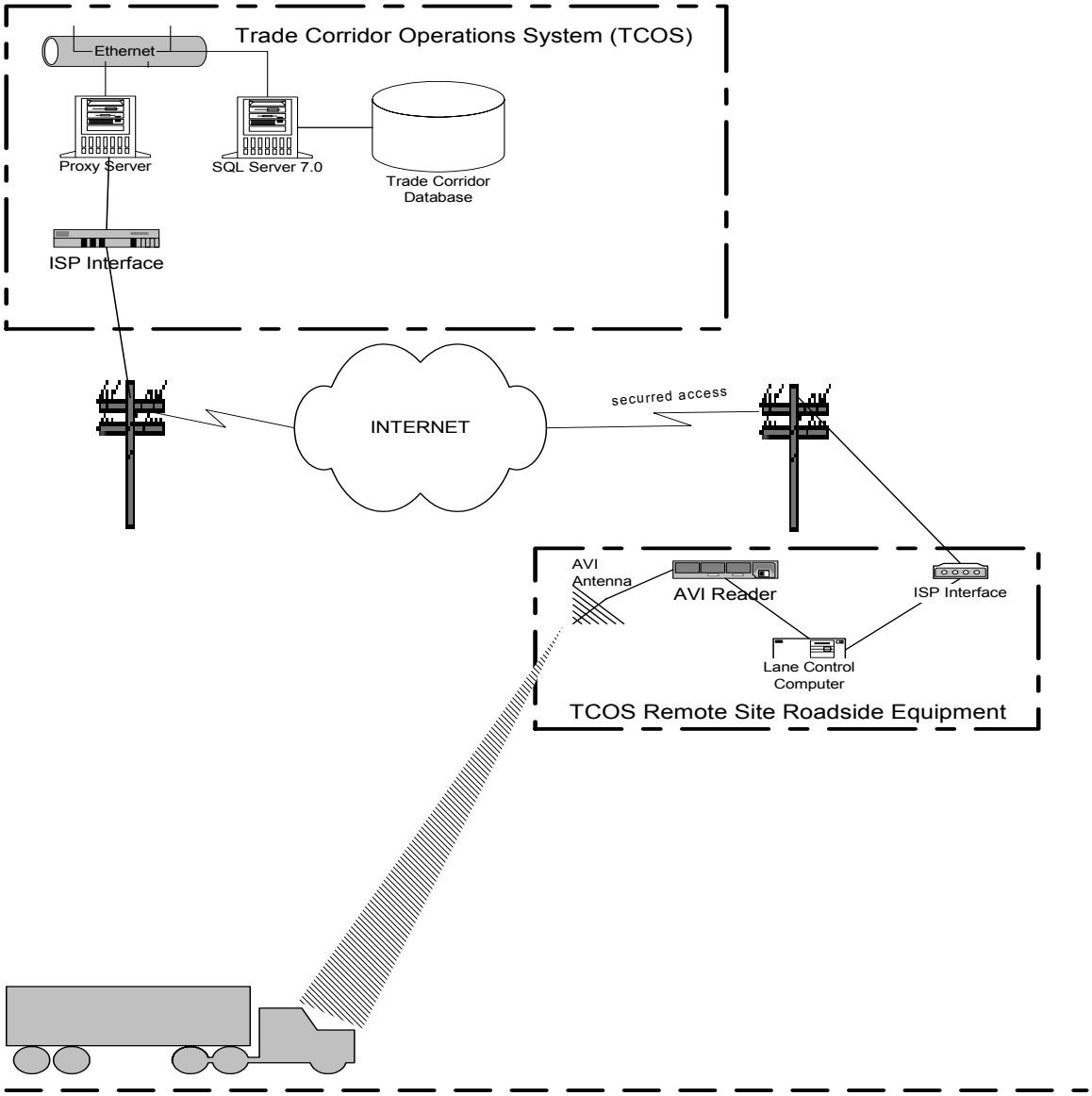


Figure 2-4. TransCore Current AVI Transponder System Architecture[5].

More specifically, the container seal number data provides a 10-byte ASCII file to the TransCore system. This data and is linked with the preceding data provided from both the now resident E-seal system data in the Maersk Sealand terminal system database, as well as the truck AVI transponder data already in the TransCore system.[6] This linking of information on the TransCore system will provide for unique identification

[5] Graphic courtesy of TransCore.

[6] The AVI reader data will be already in the system via data entry at the shipper's site. For example, at APL in Seattle, the shipping information necessary for the AVI tag is captured by a legacy system, which then uses an interface to send an automated e-mail containing the required AVI data to the TransCore system.

tracking of the container to the shipper's facility (e.g., Maersk Sealand), and the date/time of a specific event (e.g., terminal gate clearance). The event data can then be continually verified as the container and vehicle proceed through the Bow Hill weigh station and across the Canadian border.

The TransCore system provides for all tracking and data functions to be viewed and managed over the Internet. This is accomplished by the user (e.g., a shipping company) logging on to the "TransCorridor" Website, and entering in an authorized user name and password. An overview of the "container tracking view" function of this Website is provided in Figure 2-5. Here, containers highlighted in red may have a problem, and will need to stopped by USCS at the border for inspection. Containers highlighted in yellow may have some special considerations, such as a truck hauling two or three containers with the same vehicle.

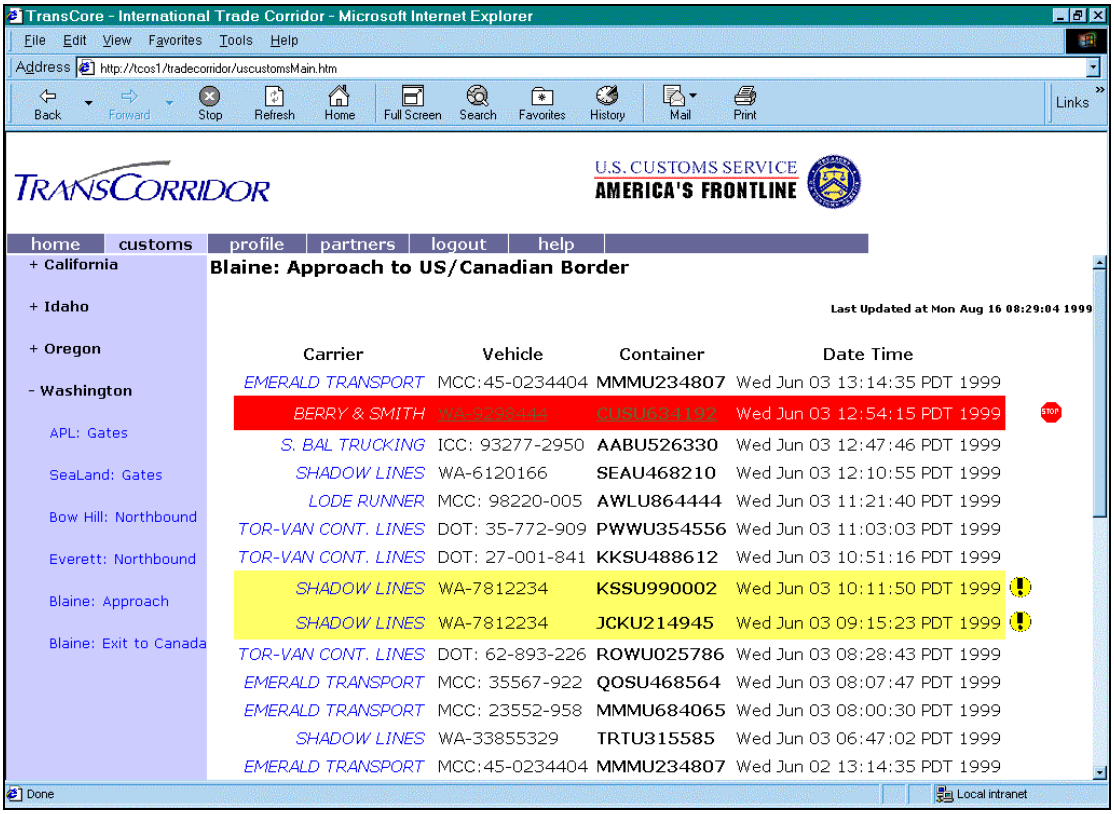


Figure 2-5. TransCorridor Website (Container Tracking View: Customs).

2.4 OVERVIEW OF THE SYSTEM OPERATIONAL ENVIRONMENT

The foundation for the entire E-seal system operational environment is communication. Intermodal transportation operations are driven by communication with the multiple parties that are involved in a given supply chain. This test involved a complex arrangement of both system-level communications and stakeholder-level communications across two different supply chains. For example, for the Maersk/ USDA supply chain, the E-seal system in this test facilitated the information exchange

between E-seal readers at a private terminal (Maersk Sealand) and at the USCS approach at Blaine, with the regional USDA inspection office. Figure 2-5 provides a high-level overview of the E-seal system and stakeholder relationships as described by the following nomenclature:

- **Facilitator**. The test was initiated and managed by WSDOT. Staff facilitated and coordinated system development, deployment, and participant recruitment.

- **Providers**. There were two primary providers associated with this test in addition to various technology vendors. New hardware was developed by e-Logicity, which included E-seals, hand-held readers, and fixed readers. TransCore integrated these components into its existing TransCorridor system.

- **Users**. There were two sets of users. USDA and Maersk Sealand used the system to track the movement of in-bond shipments of agricultural products from the Port of Tacoma to Canada. USDA staff coded, installed, and inspected E-sealed loads. USCS and Westwood used the system to track in-bond shipments of auto parts from Japan through the Port of Seattle to Canada. Westwood staff installed E-seals, and the USCS staff read and inspected the E-sealed loads.

- **E-Seal**. The E-seal was a unit of hardware that also functioned to promote security by communicating load location and status.

- **Hand-Held E-Seal Reader**. The hand-held E-seal reader was a unit of hardware used to program and read the E-seals. The hand-held reader did not communicate directly with the TransCorridor system, or any other data consolidation center.

- **Fixed E-Seal Reader**. The fixed E-seal reader was a unit of hardware that functioned to provide load visibility and status through direct communication with the TransCorridor system.

- **TransCorridor System**. The TransCorridor system is an established Internet-based system that was modified to include E-seal information. The fixed E-seal readers were connected to this system to record and enter successful reads, thereby making it possible to track individual shipments. The TransCorridor system provided the load visibility over the Internet, which supported security efforts as the system was used to “communicate” when the load had crossed the Blaine border, exiting the United States.

- **Traditional Communication Tools**. Stakeholders were heavily reliant on existing communication mediums, such as e-mail, telephone, and fax, to distribute information to trucking companies, steamship lines, regulatory agencies, and to the TransCorridor system.

The lower portion of Figure 2-6 also provides a functional description for the E-seal system. The black arrows show the directional flow of information, starting with the phone/fax shown in yellow. Once the installer receives the necessary information, the E-seal is coded via the hand-held reader. As the E-sealed container begins its journey,

it can be read by a hand-held reader (USCS) and/or a fixed reader (USDA and USCS). Through traditional e-mail channels, the E-seal information is sent to TransCore (operators of the TransCorridor system). The dashed line between “E-mail” and “TransCorridor” illustrates that although the information was available to the system, it was not entered as part of the test. Therefore, for all E-sealed containers, the TransCorridor system showed a maximum of one read.

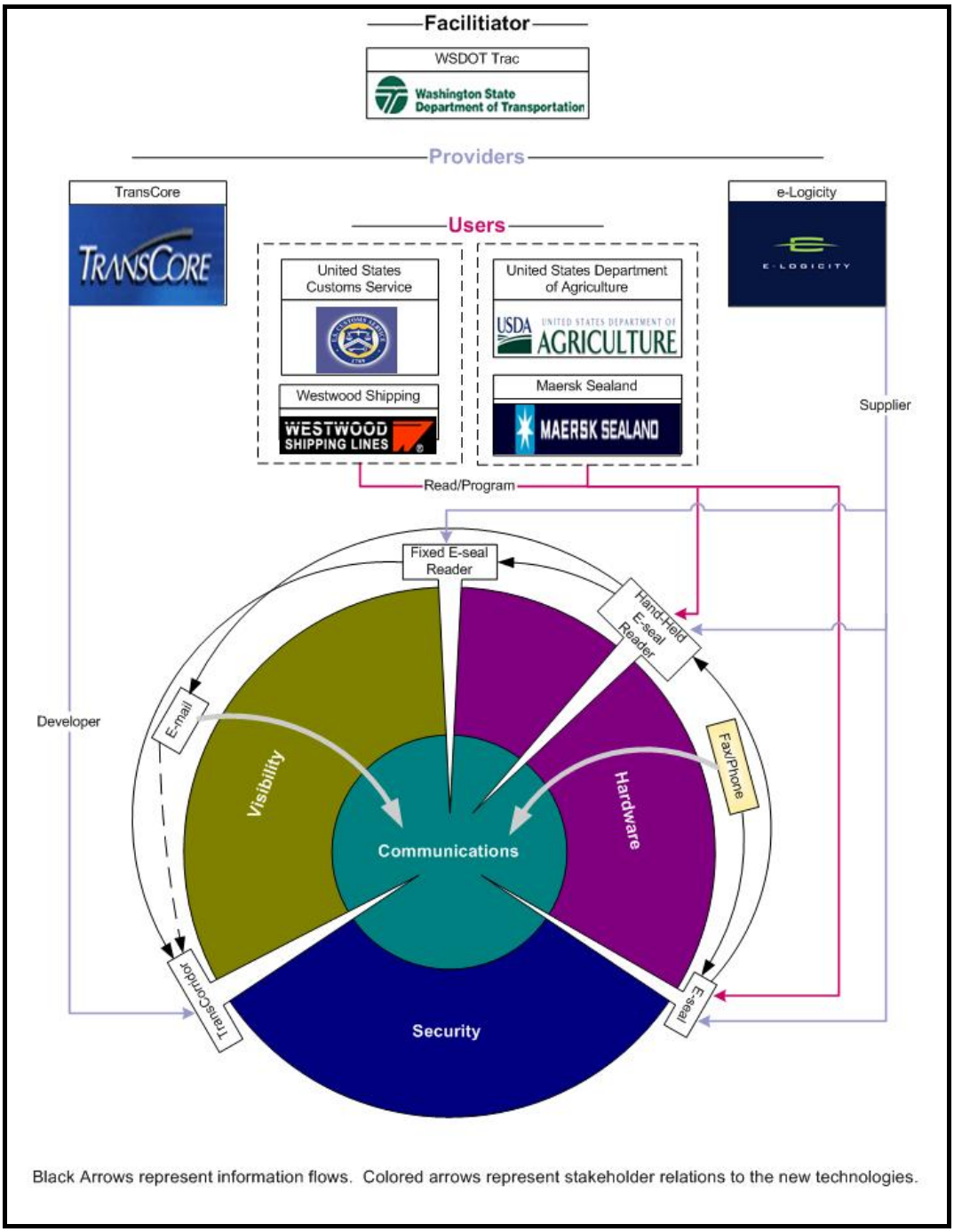


Figure 2-6. Overview of the E-Seal Operational and Stakeholder Environment.

3. TECHNICAL APPROACH

3.1 OVERVIEW

The primary objective of this test was to provide a system that allowed for improved tracking of in-bond shipments moving through the United States. It was anticipated that achieving this objective would provide benefits to the freight community and the regulatory agencies responsible for monitoring these shipments.

For the freight industry, the objectives were to provide shippers with the ability to better track their shipments across multiple modes, to facilitate their ability to meet the regulatory requirements for shipments of this type, and to increase their ability to track theft/tampering attempts. For this test, 47 E-seals were installed onto containers at two locations – the Port of Tacoma and Japan. For the initial location at the Port of Tacoma, USDA staff installed E-seals on in-bond agricultural shipments being handed by Maersk Sealand. In Japan, a Westwood agent installed 30 E-seals on containers of auto parts moving in-bond through the Port of Seattle to Canada. This included seal inspection and reading by USCS staff upon entry into the United States. Once the loads were sealed, they remained in the test until they cleared the U.S. border in Blaine, Washington.

For the regulatory agencies, the primary objective was to be able to better ensure that in-bond shipments were clearing the U.S. border in a timely manner without being opened, which will increase their enforcement capabilities and result in increased homeland security. Moreover, the champions of this FOT believed that better information from the E-seal might persuade the border enforcement agencies to allow trusted carriers to cross the border somewhat unimpeded.

The evaluation was based on the following four areas: intermodal freight system operations, customer satisfaction, institutional challenges, and technical effectiveness. The data analysis and results of these evaluations are presented in Section 4, with the first three areas combined to some extent based on their interdependence. That is, the changes in the system operations directly impact customer satisfaction and institutional challenges. The technical effectiveness evaluation is presented separately. For a detailed description of the methodologies that were developed to implement this evaluation, readers are referred to the following two reports:

"WSDOT Intermodal Data Linkages ITS Field Operational Test Final Evaluation Plan," March 28, 2001, prepared by SAIC; available at: http://www.itsdocs.fhwa.dot.gov//JPODOCS/REPTS_TE/13475.pdf

"WSDOT Intermodal Data Linkages ITS Field Operational Test Evaluation Detailed Test Plans," May 31, 2002, prepared by SAIC; available on request from SAIC.

To execute the evaluation detailed test plans, data were primarily collected from the participants through personal interviews to measure overall perceptions, site visits to observe the system in use, and collection of statistical data reports from the system and others (both manual records and system-generated reports). Data were collected

throughout the duration of the test to document expectations and evolving perceptions on the system itself.

This system provided archived data concerning the tracking capabilities through the TransCorridor system Website, which enabled USDA and USCS to verify departure from the United States. Although Website access could have been used by individual participants to track specific loads, it was not used in this manner for this FOT. The system was secure, and allowed the Evaluation Team and regulatory agencies such as USCS and USDA access to all records. Private companies were only able to access and review their own records.

The heart of the technical approach for this evaluation involved detailed mapping of "before and after" supply chain processes for each of the two tests: USDA/Maersk Sealand and USCS/Westwood. The following sections present the results of this process mapping activity. Based on this process definition, the evaluation methodologies outlined in the detailed test plans were implemented, and the data analysis and results from these evaluation activities are presented in Section 4.

3.2 USDA/MAERSK SEALAND TEST PROCESSES

The first test deployed for the USDA used electronic seals to track produce shipments moving through the Port of Tacoma in-bond to Canada. Based on Government Accounting Office (GAO) findings, the existing procedures for tracking these shipments were inadequate. The USDA recognized the need to develop a new program to monitor these types of shipments. It was determined that E-seals could be used to verify that the produce loads were departing the United States within hours of departing the Port of Tacoma.

The USDA/Maersk Sealand pre-deployment and deployment flows of freight and information are color-coded and shown in Figures 3-1 and 3-2, respectively. Green represents points of freight flow; purple represents information flow; red signifies a problem; and yellow illustrates the new procedures and steps created by the E-seal program. The major differences between the existing and test conditions consist of additional steps that must be completed by USDA, Maersk Sealand, and PRTI. These additional steps increased the level of effort for all three participants.

The USDA/ Maersk Sealand test process was conducted using the following steps:

1. Maersk Sealand notified USDA that a "permit" load was ready.
2. USDA coded and installed an E-seal at the Port of Tacoma.
3. USDA faxed the E-seal-related paperwork from USDA Tacoma to USDA Blaine.
4. USDA Tacoma e-mailed the E-seal information to Transcore.
5. Maersk Sealand initiated fax/phone communication with PRTI.

6. E-seals were read electronically at the Blaine crossing to record load arrival time by the fixed reader, and verified the load at Blaine by requiring the driver to stop and communicate with a USDA agent.

7. The truck was allowed to exit the United States and proceed into Canada.

The USDA/Maersk Sealand process is illustrated in Figures 3-3 through 3-6. Figure 3-3 shows a USDA staff member coding an E-seal before it is installed on the back of a truck (as shown in Figure 3-4). Figure 3-5 shows the northbound approach lanes for trucks exiting the United States and traveling into Canada at Blaine. Figure 3-6 shows the transponder readers installed at the northbound Blaine border crossing.

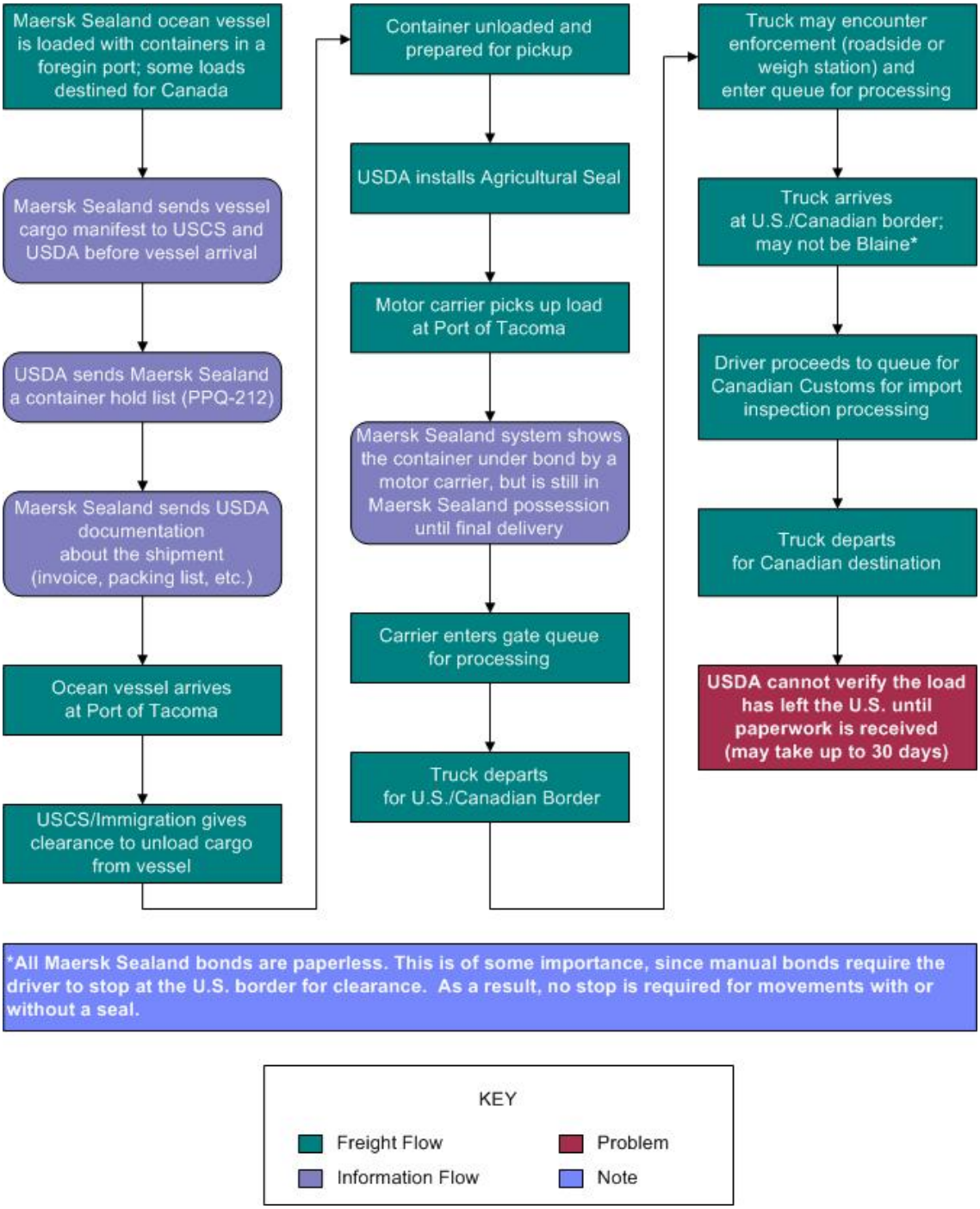


Figure 3-1. Existing Flow of Freight and Information for USDA/Maersk Sealand.

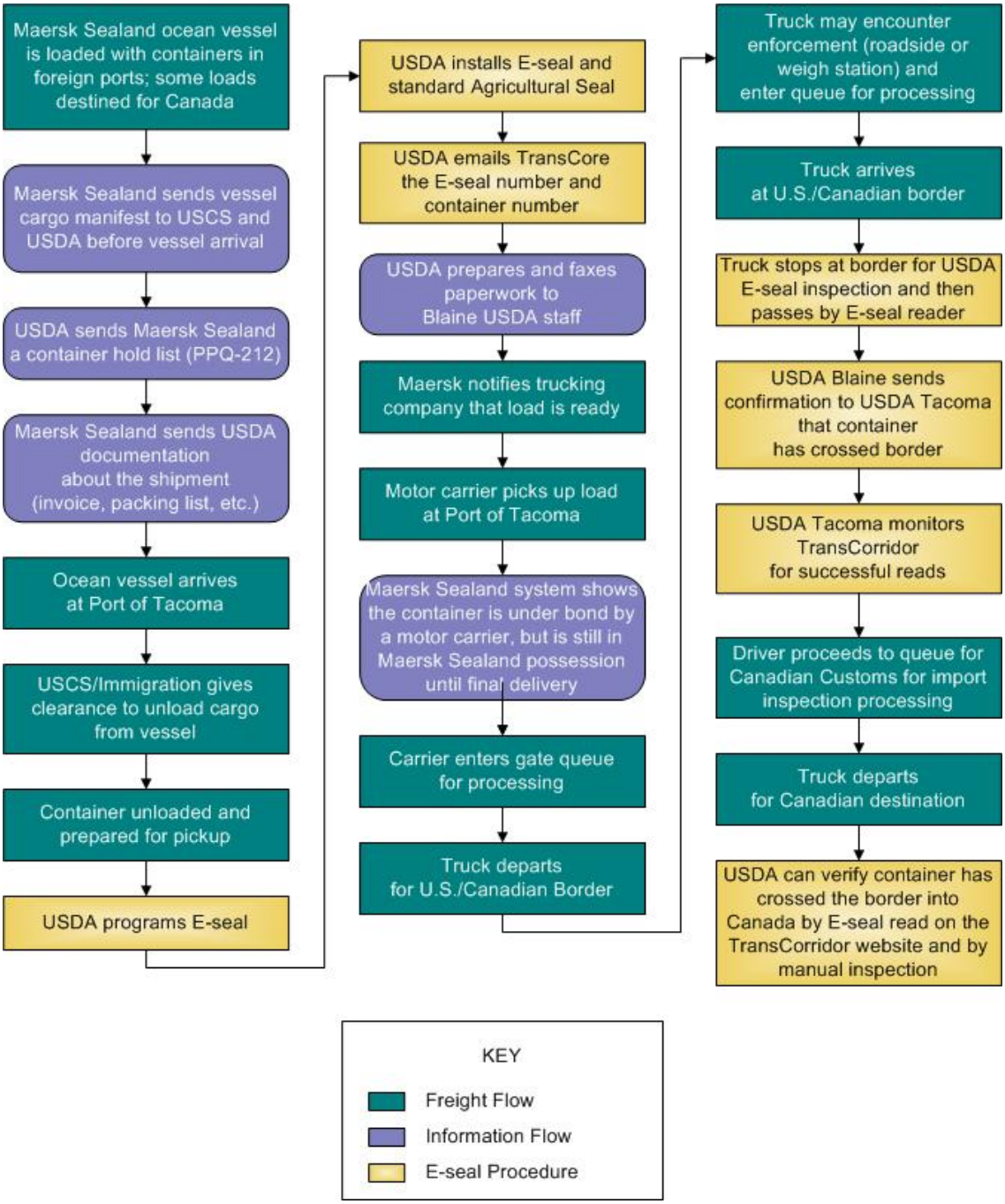


Figure 3-2. E-Seal Flow of Freight and Information for USDA/Maersk Sealand.

Figure 3-3. E-Seal Being Coded Prior to Installation.

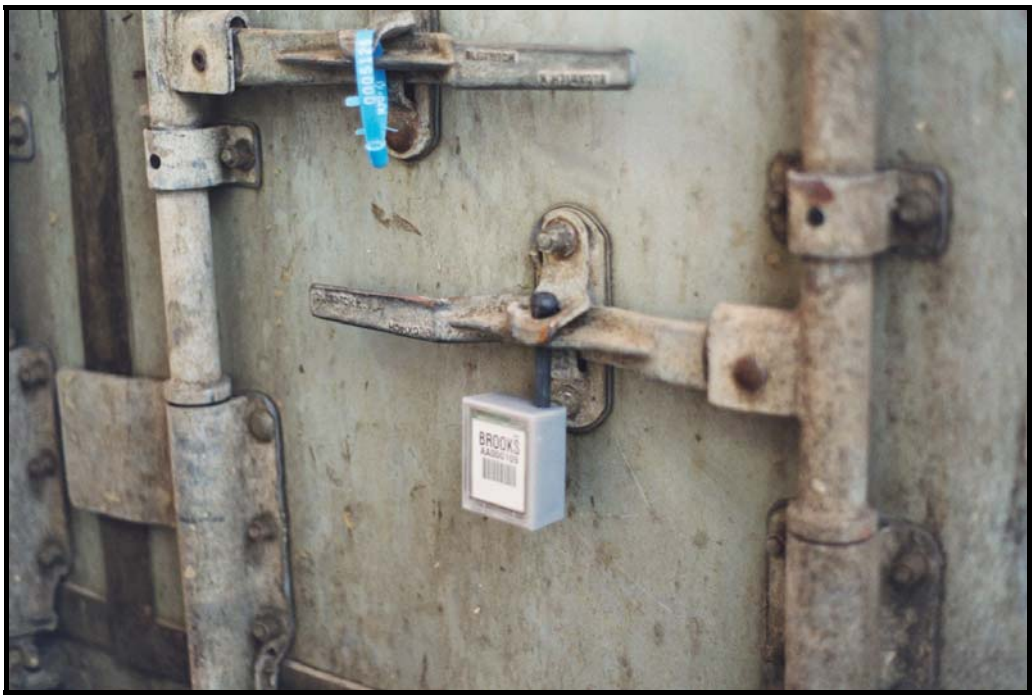


Figure 3-4. E-Seal Installed on a Container.

Figure 3-5. Approach Lanes at Blaine Border Crossing (Northbound).

Figure 3-6. E-Seal Readers (TV-like Antennas) and Transponder Readers (Flat Antennas) Installed over a Truck Lane at the Blaine Border Crossing.

3.3 USCS/ WESTWOOD TEST PROCESSES

The second FOT was deployed for the USCS to track auto parts shipments moving from Japan through the Port of Seattle in-bond to Canada. The USCS has been under the same pressures as the USDA to provide a better tracking mechanism for in-bond shipments. In fact, the USCS was the original regulatory agency slated for participation in the E-seal test. However, USCS participation was delayed until Westwood Shipping Lines agreed to join the test in the spring of 2002.

The USCS/Westwood Shipping Lines (Westwood) pre-deployment and deployment flows of freight and information are color-coded shown in Figures 3-7 and 3-8, respectively. In the diagrams, green represents points of freight flow; purple represents information flow; and yellow illustrates the new procedures and steps created by the E-seal program. Again, the major differences consist of additional activities required of Westwood, USCS, and PRTI.

The USCS/Westwood test process was conducted using the following steps:

1. Westwood installed the E-seal in Japan.
2. Westwood contacted USCS to announce that loads were available for inspection.
3. USCS verified the E-seal status at Port of Seattle.
4. USCS provided read results to Transcore.
5. Load departure from the Port of Seattle.
6. Load arrival at the Blaine crossing.
7. E-seal was read at the border.
8. Load proceeds to Canadian Customs, pending any other border activity.

The USCS/Westwood process is illustrated in Figures 3-9 through 3-12. (The pictures previously shown in Figure 3-3 through 3-6 also reflect this process.) Figures 3-9 and 3-10 show the Westwood container ship at Port of Seattle being unloaded.

Figures 3-11 and 3-12 show USCS staff reading the E-seal at Terminal 5 in Seattle after the container has been off loaded from the vessel. Figure 3-11 represents the actual reading of the seal by the hand-held reader and Figure 3-12 displays the screen shot from the reader itself showing a status of “normal”.

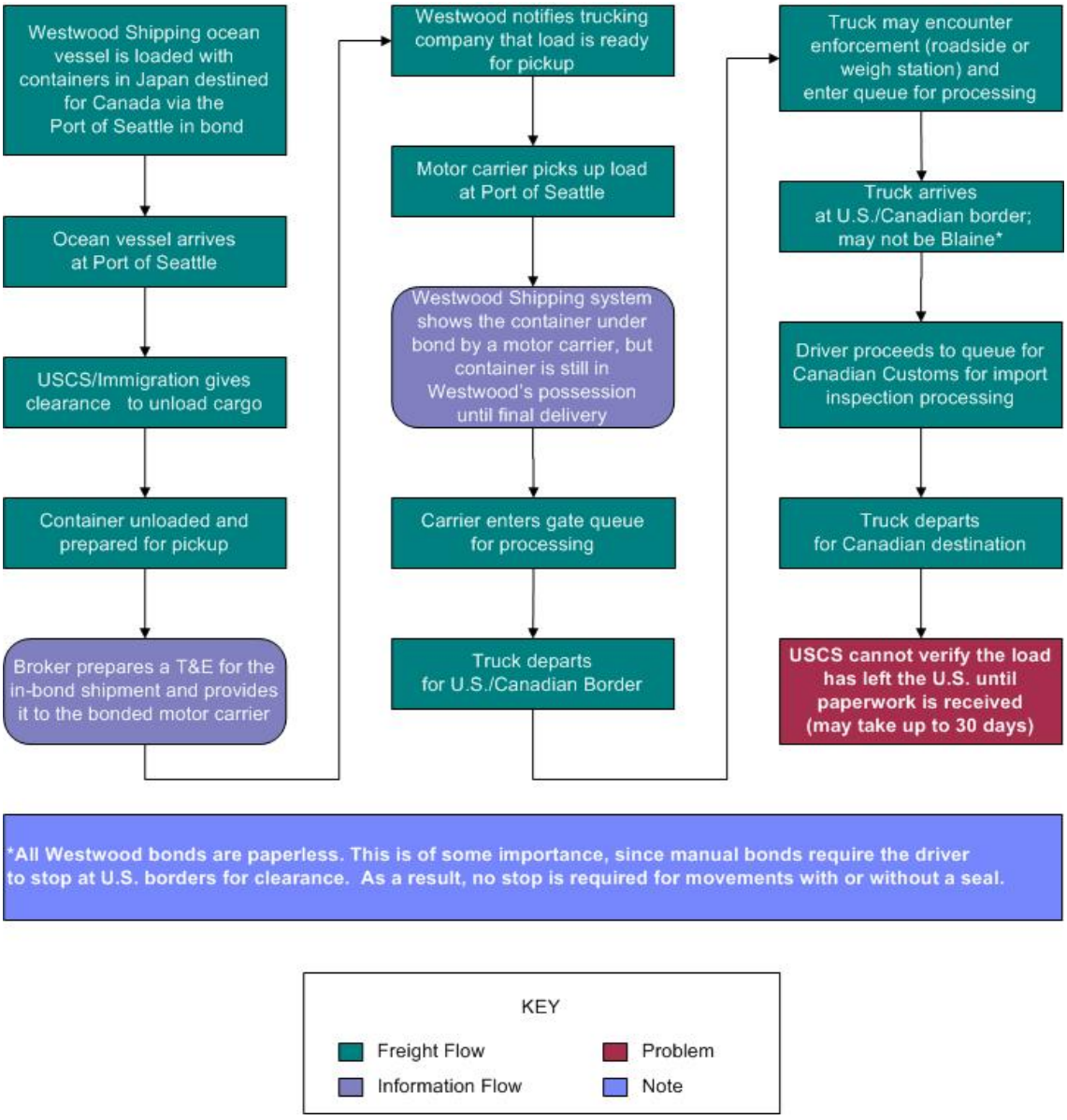


Figure 3-7. Existing Flow of Freight and Information for USCS/Westwood.

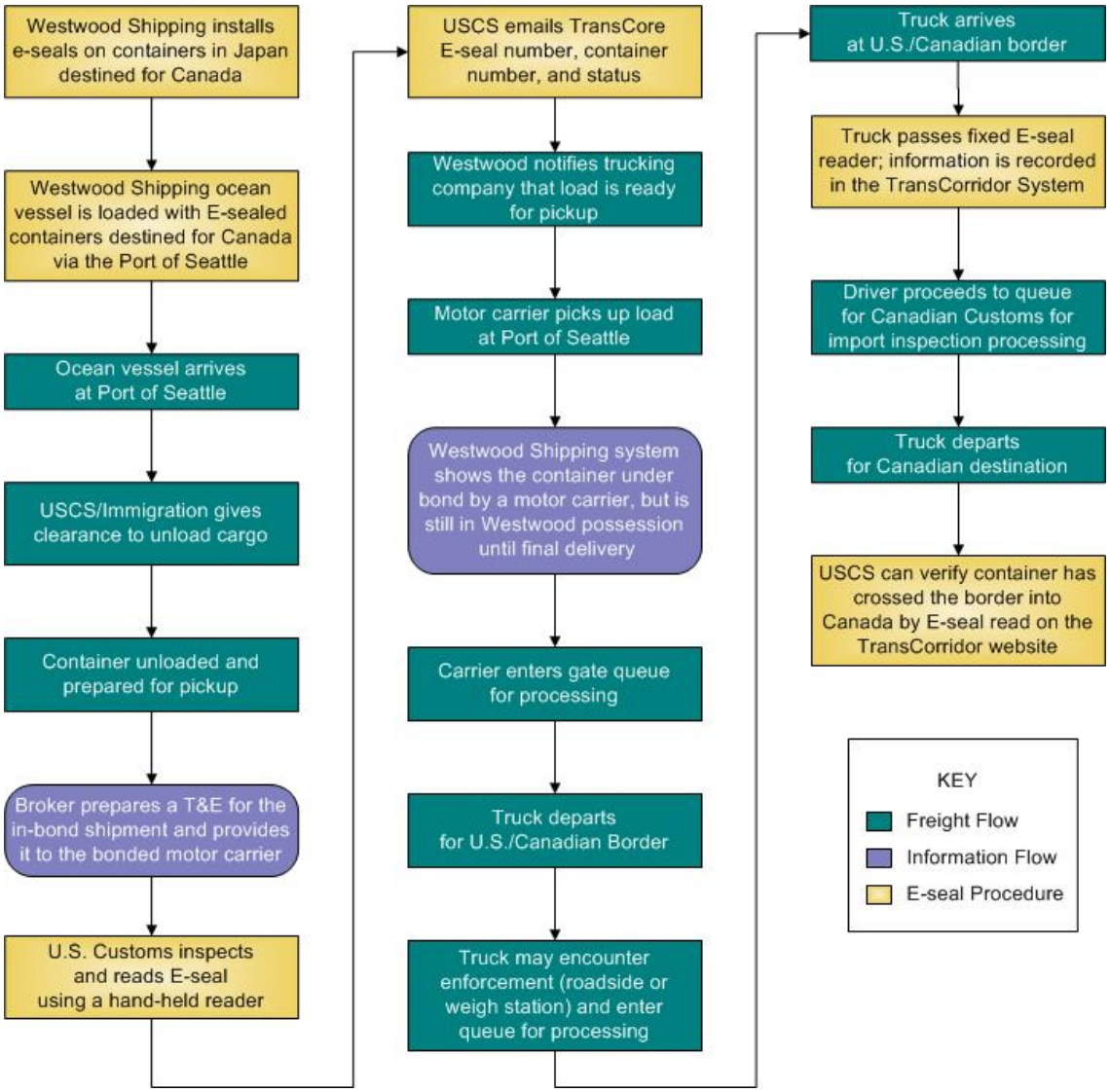


Figure 3-8. E-Seal Flow of Freight and Information for USCS/Westwood.

Figure 3-9. Westwood Shipping Lines Container Vessel at Port of Seattle.

Figure 3-10. Offloading of Containers at Port of Seattle.

Figure 3-11. E-Seal Being Read.

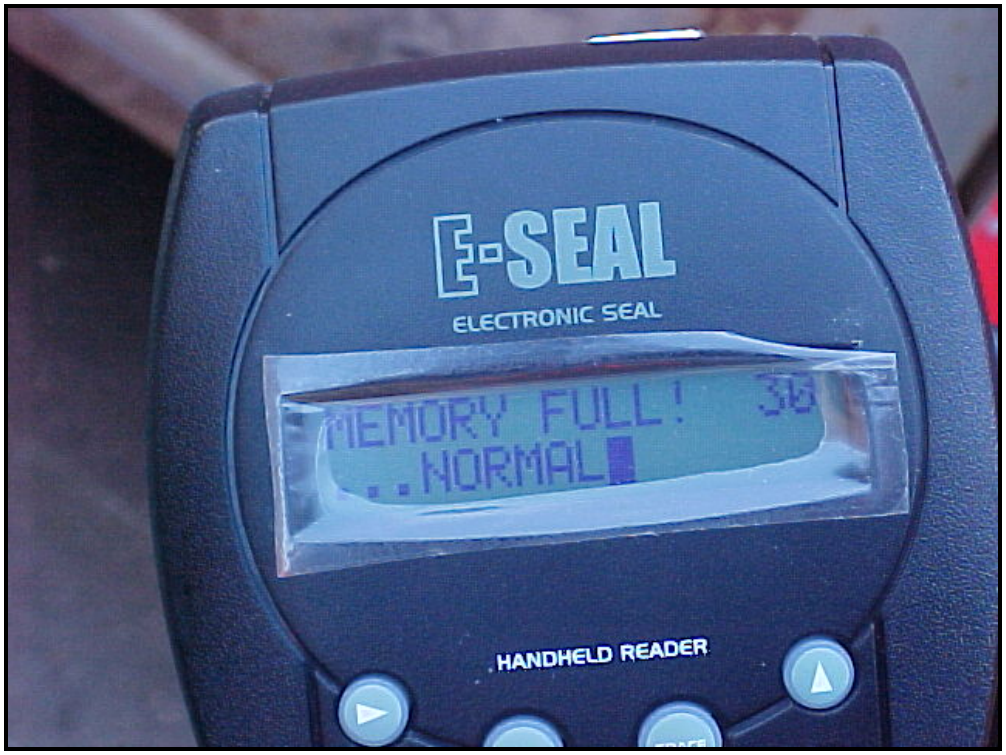


Figure 3-12. Hand-held E-Seal Reader Display Screen Indicating a "Normal" Reading.

4. DATA ANALYSIS AND RESULTS

The E-seal test was evaluated based on a variety of data. This section presents the data collected and analyzed, and is organized around the following sections:

- 4.1 Analysis of E-Seal System Operational Performance
- 4.2 Summary of Participant Satisfaction and Identified Institutional Challenges
- 4.3 Analysis of the Technical Effectiveness of the System

4.1 ANALYSIS OF E-SEAL SYSTEM OPERATIONAL PERFORMANCE

As part of the technical effectiveness evaluation, a detailed analysis was conducted on the E-seal system and its functionality. This section presents E-seal activity from an operational perspective. Specifically, it presents the E-seal activity and results for the two tests (USDA/Maersk and USCS/Westwood), which are described as follows.

4.1.1 USDA/ Maersk Sealand Test

The first phase of the USDA/Maersk Sealand test occurred between March and early August 2002, and consisted of installing 47 E-seals (two or less per week). The TransCorridor data showed a read rate for these E-seals at 55 percent, with 26 out of 47 E-Seals being successfully read. Figure 4-1 and Table 4-1 provide the system data.

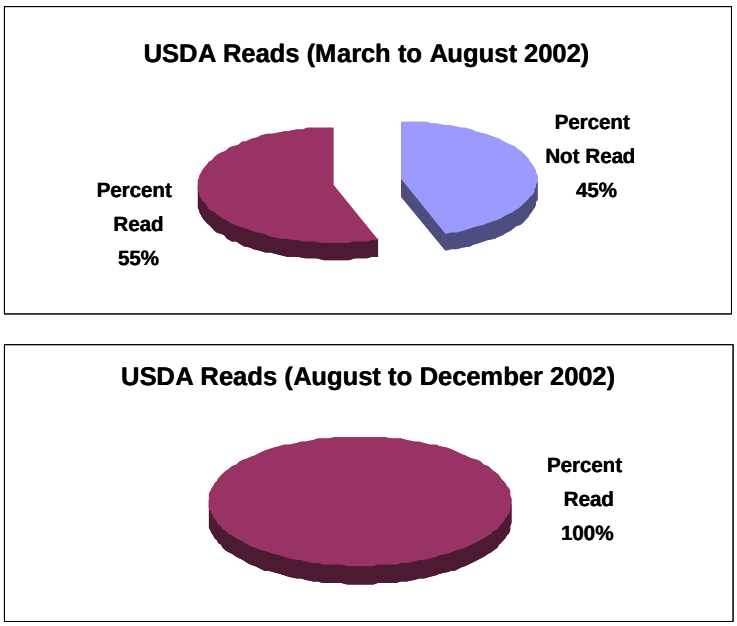


Figure 4-1. Maersk/USDA E-Seal Read Results for Blaine.

Table 4-1. Maersk/USDA E-Seal Read Results from the TransCorridor System (March to August 2002)

Date	Time Read	Container	E-seal	Read
07/30/02	03:25:25 PM	MHHU560993	AA000169	Y
07/29/02	11:48:24 AM	TPHU482169	AA000159	Y
07/24/02	Not Read	SEAU210304	AA000158	N
07/15/02	Not Read	HDLU400294	AA000140	N
07/15/02	Not Read	CMBU406984	AA000137	N
07/08/02	12:54:24 PM	MSKU224343	AA000154	Y
07/08/02	05:36:02 PM	MAEU775397	AA000156	Y
07/08/02	01:27:04 PM	AMPU451866	AA000153	Y
06/17/02	Not Read	Unknown	AA000149	N
06/10/02	12:56:12 PM	MAEU518309	AA000132	Y
06/10/02	01:01:53 PM	MSAU544068	AA000135	Y
06/10/02	Not Read	MWCU650272	AA000148	N
06/10/02	Not Read	MWCU650843	AA000133	N
06/10/02	Not Read	MWCU621363	AA000138	N
06/05/02	Not Read	MLCU432015	AA000151	N
06/05/02	12:40:41 PM	MSKU228320	AA000150	Y
06/04/02	01:04:44 PM	MWCU613752	AA000147	Y
06/03/02	01:33:07 PM	SEAU787084	AA000142	Y
06/03/02	12:27:20 PM	MSKU208233	AA000145	Y
05/24/02	11:53:18 PM	Unknown	AA000134	Y
05/14/02	01:50:28 PM	Unknown	AA000126	Y
04/25/02	12:56:13 PM	SEAU782617	AA000128	Y
04/18/02	12:42:09 PM	Unknown	AA000118	Y
04/18/02	12:03:47 PM	Unknown	AA000116	Y
04/17/02	02:13:18 PM	MWCU606652	AA000117	Y
04/10/02	Not Read	MAEU581966	AA000120	N
04/10/02	12:18:05 PM	MAEU578303	AA000124	Y
04/10/02	12:10:18 PM	MWCU608134	AA000112	Y
04/05/02	01:36:51 PM	MAEU577099	AA000114	Y
04/02/02	02:48:09 PM	SEAU525629	AA000111	Y
04/01/02	12:57:35 PM	MWCU654780	AA000143	Y
03/27/02	Not Read	MAEU576151	AA000123	N
03/21/02	02:16:28 PM	MWCU613878	AA000122	Y

Date	Time Read	Container	E-seal	Read
03/14/02	Not Read	MAEU831897	AA000047	N
03/14/02	Not Read	SEAU850944	AA000048	N
03/14/02	Not Read	CAXU605074	AA000045	N
03/14/02	Not Read	MAEU730447	AA000050	N
02/28/02	Not Read	MAEU468434	AA000109	N
01/30/02	Not Read	MAEU573278	AA000103	N
01/29/02	01:17:23 PM	MHHU562812	AA000102	Y
01/18/02	Not Read	MAEU576064	AA000030	N
01/03/02	09:11:06 AM	MAEU606958	AA000028	Y
01/02/02	Not Read	MAEU553605	AA000031	N
01/02/02	Not Read	MAEU574998	AA000032	N
12/26/01	Not Read	MWCU657407	AA000026	N
12/22/01	Not Read	MWCU653154	AA000025	N
12/18/01	Not Read	MWCU606866	AA000024	N

There are many variables that explain the 47 percent of E-seals that were not read during this initial period (March to August 2002). The USDA staff were the first individuals to install and use the seals. In fact, 12 of the first 14 E-seals were not read. Participants reported that this was the result of drivers exiting the United States at the wrong border crossing. It should be noted that this process of requiring a specific border crossing was new for the drivers. In addition, the same trucking company handled the Westwood shipments many months after USDA began using the system, so the shipping staff were already well trained on the requirements.

However, as a result of the initial failure rates, the USDA changed its procedure to require the truck drivers to stop at Blaine and undergo a physical inspection of the E-seal conducted by USDA staff. That intervention, along with a stronger familiarity with the procedure, created a higher read rate on subsequent shipments.

Following that process change, there were additional failures attributed to several different factors: additional crossings at the wrong location; errors in E-seal installation; and unscheduled down time of the TransCorridor server. The remaining 33 E-seals deployed by USDA had an almost 70 percent read rate. This higher result illustrates that when the system is up, functioning correctly, and all participants are properly trained, the system was a success.

As shown previously in Figure 4-1, these operational issues were corrected in the second portion of Maersk/USDA test which took between August and December 2002. Here, 12 of 12 E-Sealed containers (100 percent) were successfully read by USDA inspectors. This test effectively validated the success of the Transcore/e-Logicity system as applied to the Maersk/USDA E-Seal supply chain.

It should be noted that the E-seal information collected by the USDA staff at Port of Tacoma (coding and successful read) was provided via e-mail to TransCore. These data were not entered into the TransCorridor system. However, USDA Blaine staff manually inspected all containers that crossed at Blaine and followed the procedure, so USDA actually had a higher manual rate of inspection than the numbers represented in the preceding Figure 4-1 and Table 4-1.

4.1.2 USCS/Westwood Test

During the spring of 2002, Westwood installed 30 E-seals in Japan as part of the initial portion of this test ("Round 1"). All 30 E-seals were inspected and read using hand-held readers by USCS officers at the Port of Seattle. Three E-seals registered as being "tampered" with during the read process. Of the 30 E-seals installed, 20 percent (or six) were not read at the Blaine border crossing, as illustrated in Figure 4-2 and Table 4-2. Participants believe read failures were due to a malfunctioning fixed reader at the border and not the actual seal.

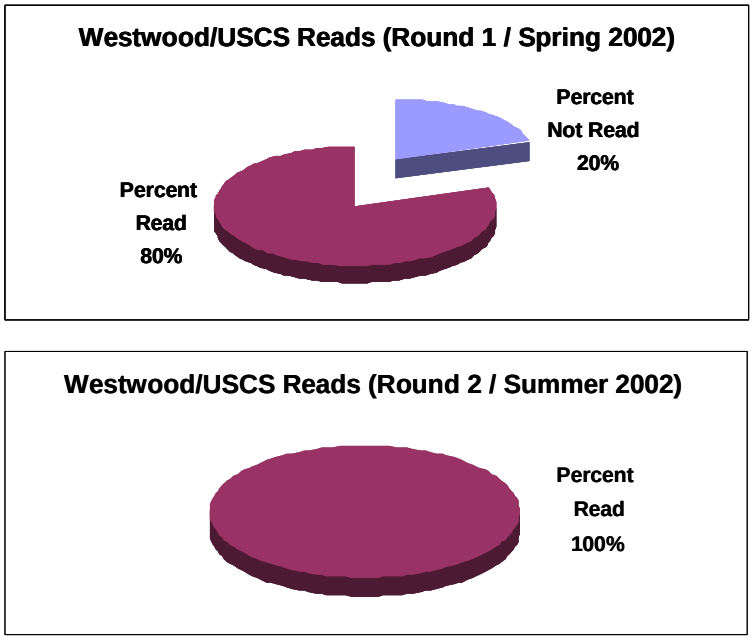


Figure 4-2. Westwood/USCS E-Seal Read Results for Blaine.

Table 4-2. Westwood/USCS E-Seal Read Results from the TransCorridor System (Round 1/Spring 2002)

Date	Time Read	Container	E-seal	Read
06/26/02	03:48:23 PM	TOLU355327	AA000551	Y
06/26/02	01:02:22 PM	TOLU362812	AA000553	Y
06/26/02	12:42:40 PM	CAXU472796	AA000546	Y
06/26/02	Not Read	GATU415908	AA000548	N
06/26/02	Not Read	TOLU219586	AA000549	N
06/21/02	11:58:35 AM	CAXU433031	AA000538	Y
06/21/02	01:55:01 PM	GATU415723	AA000539	Y
06/21/02	01:55:22 PM	GSTU848967	AA000541	Y
06/21/02	01:17:34 PM	TEXU718304	AA000542	Y
06/21/02	03:10:51 PM	TOLU228284	AA000543	Y
06/12/02	07:32:01 PM	TEXU407019	AA000534	Y
06/12/02	07:34:03 PM	GATU435483	AA000533	Y
06/12/02	07:34:08 PM	TRIU550373	AA000537	Y
06/12/02	07:41:38 PM	TRIU541080	AA000536	Y
06/12/02	Not Read	TRIU530595	AA000535	N
06/06/02	02:52:02 PM	GATU409712	AA000936	Y
06/06/02	01:01:11 PM	TOLU151841	AA000530	Y
06/06/02	02:00:03 PM	TRIU569708	AA000531	Y
06/06/02	12:20:58 PM	TEXU464183	AA000527	Y
06/06/02	Not Read	GATU425225	AA000526	N
05/29/02	02:13:21 PM	CAXU465814	AA000509	Y
05/29/02	01:57:18 PM	TRLU457784	AA000514	Y
05/29/02	02:09:34 PM	TRIU530665	AA000513	Y
05/29/02	03:15:21 PM	WSLU487209	AA000518	Y
05/29/02	Not Read	WSLU486727	AA000516	N
05/22/02	12:14:36 PM	TRLU621710	AA000504	Y
05/22/02	03:56:53 PM	WAXU705486	AA000507	Y
05/22/02	02:22:10 PM	WAXU720242	AA000508	Y
05/22/02	02:23:26 PM	WSLU487417	AA000506	Y
05/22/02	Not Read	WSTU993861	AA000505	N

Read failures during Round 1 were likely to result from a truck being in the wrong lane, placing the E-seal too far away from the reader, or unscheduled down time of the TransCorridor server.

In addition to the system reads, during Round 1, USCS staff provided TransCore with the E-seal read status at the Port of Seattle via traditional communication methods (most frequently via e-mail). These data were not entered into the TransCorridor system. The three E-seals identified as being “tampered” with were based on the manual record keeping of the USCS staff.

As shown above in Figure 4-2, these operational issues were corrected in the second portion (“Round 2”) of the USCS/Westwood test, which took place over the summer of 2003. Here, 28 of 28 E-Sealed containers (100 percent) were successfully read at the Blaine USCS station. This test effectively validated the success of the Transcore/ e-Logicity system as applied to the USCS/Westwood E-seal supply chain.

4.2 SUMMARY OF PARTICIPANT SATISFACTION AND IDENTIFIED INSTITUTIONAL CHALLENGES

A significant component of the E-seal system test was to determine how well the system worked from an operational and institutional perspective. Specifically, how difficult was it to develop and deploy, and how satisfied were the users with its functionality. The following section summarizes feedback obtained by the Evaluation Team over the course of the entire test from the participants. The summaries are organized around the two tests.

4.2.1 USDA/Maersk Sealand Test

The following information summarizes the participant satisfaction and institutional challenges identified by the Evaluation Team for the USDA/Maersk Sealand supply chain test over the course of this study. Information was derived via interviews, analysis of operational performance, and direct observation.

- **Difficult Installation**. Initially, successful installation of the E-seals was a problem. USDA staff found the E-seals to be difficult to install correctly. The E-seals seemed to be extremely sensitive and staff had to perfect the installation. Primarily, this required one smooth movement to install the bolt. Any deviation or failed attempt made the E-seal unusable. In addition, several E-seals were found to be nonfunctional even before installation began. TransCore also acknowledged that additional training for E-seal installation was required to eliminate these problems.

- **Inconsistent Lane Coverage**. The fixed E-seal reader at Blaine did not cover all lanes. This resulted in missed reads of some E-seals and is attributed to driver training.

- **System Down Time**. There have been a few instances when the TransCorridor system went down, both unexpectedly and intentionally during the test. The server crashed a few times due to software problems, Internet ISP service, etc. These instances were dealt with as expeditiously as possible. Regarding the scheduled down times, it was unclear to USDA staff that this would impact their operations, which resulted in missed reads at Blaine. Since these events, a communication protocol has been implemented to ensure all participants are knowledgeable about

these down times. Since the updated system came on line in June, the system has not gone down.

- **Effective Shipment Identification**. USDA was able to effectively use the E-seal system to identify a shipment that left the system. The E-seal program was a benefit because when the load failed to meet the 4-hour window, USDA was able to react in half the usual time without the system. In this instance, one driver skirted the Blaine crossing, and used another crossing. It took the driver 6.5 hours to reach the border crossing (violating the 4-hour window) and Canadian Customs staff did not record any seal number in its paper work. Therefore, it was assumed the load was opened prior to the driver reaching the border. As of October 2002, both the driver and load are still missing, and an ongoing investigation is in progress. It is expected that the E-seal system will assist with prosecution when the driver is apprehended.

- **Difficulty in Use**. USDA staff members have found the hand-held readers to be difficult to use. Records can only be deleted one at a time; the batteries run down too quickly; the readers are large and awkward; the readers have too many features that have not and would not be used by USDA that make them more complicated to use (have to maneuver through many menus, etc.). TransCore also acknowledged having to replace USDA's hand-held unit twice due to technical failure.

- **Operational and Institutional Barriers**. There are operational and institutional barriers to automatic upload of hand-held reader data to centralized systems. Inspectors are not going to hook their readers up to a computer for download; this action is not feasible and won't happen, at least not without significant pressure from management. In addition, USDA staff members are not allowed to connect their readers to the USCS system because it is not a sanctioned unit. USDA releases containers in its automated container system (ACS) once the containers have cleared Blaine; given the lack of system integration, this requires data entry. TransCore did report that software could be written to provide an interface and that a data format for these uploads had already been defined in the TransCorridor system.

- **Limited Functionality**. From an operational perspective, it is recognized that until the system is fully deployed, it will have limited functionality. USDA expectations have decreased over the course of the test based on this perspective. The development of guidelines and/or a commitment to the system would be required to stimulate full deployment.

- **Additional Fixed Readers Required**. Additional fixed readers would have made the system more functional. Specifically, readers at the Port of Tacoma and half-way between Tacoma and Blaine would have made it possible to track a shipment more effectively. Without a mainline reader at the Port, delays in departure are a problem to manage (if a container is sealed on Friday and not picked up for delivery until Monday, USDA only knows the departure time by placing phone calls to Maersk Sealand). A gate reader would alleviate this problem.

- **More Fully Developed System**. USDA would like to have seen the existing system more fully deployed/developed prior to the expansion for southbound traffic. There is a belief that the available resources were spread too thinly. The northbound infrastructure should have been more complete as opposed to spending limited funds to bring another partially completed system online for southbound traffic.

- **High-Speed Read Test Difficulty**. The high-speed read test at Blaine (having trucks pass the readers at Blaine at higher speeds) was difficult because it required the drivers to park south of the border about one-half mile from the office; walk down a hill to the border, and then walk back up the hill with the inspector. Many truck drivers were very annoyed at having to walk a mile. In fact, some of the inspectors were harassed as a result of this request. Also, it was difficult to enforce because it was not required by law that they do this. Essentially, the technology worked but the operational scenario was not effective.

- **Participants' Level of Commitment**. The USDA test differed from the USCS test in that the private sector participants did not really have a choice. It was voluntary; however, it was also required for the in-bond shipments being moved. Therefore, Maersk Sealand and PRTI were fully committed to the test to ensure that they were able to maintain their business.

- **Border Stopping Requirements**. The Maersk Sealand shipments involved in this test had electronic bonds. Under normal (non-test) conditions, shipments of this type are not required to stop at the border for inspection. Therefore, participation in this test required additional border time for the drivers. This procedure was further complicated that for many truck drivers, since English was their second language. There were reports at the beginning of the test that there was some confusion at the border by regulatory staff as to why these trucks were stopping.

- **Time Availability Issues**. The E-seal test greatly increased the amount of work required per shipment due to duplicative systems, record keeping, and coordination efforts. In addition, the requirement that trucks must cross the border between 8 a.m. and 4:30 p.m. has complicated operations. Twenty-four hour availability for border crossing is necessary.

- **Participant Reactions**. Maersk Sealand recognizes this has been a test, but is happy to have been able to participate in it to keep its customers. USDA focuses on inbound shipments to the United States; therefore, the E-seal test on outbound shipments at Blaine required additional staffing for northbound traffic.

  - USDA has developed duplicative manual and automated systems relying on existing and new communication technology. Staff record and fax paper work as well as use e-mail and the TransCorridor system. This has been done so they can confirm loads have exited the United States even if the E-seal system fails.

  - All participants were fitting this test into their existing business activities, which at times complicated operation of the system based on individual

priorities. Overall, participants felt the system has a lot of potential for when it is fully deployed.

4.2.2 USCS/Westwood Test

The following provides a summary of the identified participant satisfaction and institutional challenges identified by the Evaluation Team for the USCS/Westwood supply chain test over the course of this study via interviews, analysis of operational performance, and direct observation.

- **Difficult Installation**. The initial setup for USCS/Westwood proved to be challenging. E-seal installation in Japan required overcoming labor and cultural issues. Some problems included the need for training for E-seal installation and coding. Initially, it was proposed that the seals be installed at the factory but this proved difficult. The solution was to have the Westwood agent install the seals at the actual port in Japan.

- **Coordination and Role Assignments**. Coordination among the Terminal (T-5) in Seattle, USCS, and Westwood was critical. Roles and responsibilities had to be assigned. Westwood coordinated with the Terminal to determine when the containers were unloaded from the ship and ready for export. Then Westwood notified USCS, and an inspector arrived with a hand-held reader to meet the clerk at the Terminal. The clerk took the inspector to the containers, where each container was read by the hand-held reader. (Westwood had to reimburse the Terminal for the clerk's time to take USCS to the container.)

- **System Deployment**. Due to the test schedule length (nearly 6 weeks), Westwood had to deploy the system carefully, as there was not enough time to fully educate all indirect participants. To eliminate any problems that might occur with the customer in Canada, the E-seals were removed by the truck driver before the containers entered the CN Rail Yard en route to their final destination. In future deployments, Westwood prefers to more fully involve the shippers and provide them with the results of the E-seal reads. There should be a value-added tracking and security feature to enable Westwood to allow customer participation.

- **More Communication Desired**. Westwood recommends more communication and more advanced planning in the future with USDOT, USCS, and Canadian Customs. This is primarily due to the fact that Westwood was recruited late in the test and was not involved in the last several years of planning, development, and coordination.

- **Border Stopping Requirements**. USCS, like USDA, is primarily focused on inbound shipments entering the United States. Since in-bond movements must be closed out as having exited the country, this was viewed by USCS as a useful test. From an enforcement point of view, if the E-seal fails at the border, there needs to be immediate action to stop the truck, since within seconds, the truck is no longer within USCS jurisdiction. A red/green light system was suggested as one way to manage this issue. Automated border clearance is a valid goal, but it should be recognized that USCS and USDA are not the only regulatory agencies at the border that require vehicles to stop. For example, both the U.S. Immigration and

Naturalization Service (INS), as well as Canadian Customs, have their own requirements, and neither agency were participants in this test.

- **Installation Integrity**. USCS also recognizes that the E-seal is only as good as the person who installs it. If this is done in a foreign port by non-USCS staff, then there will always be a question of shipment integrity. The installation by Westwood's agent in Japan proved the technology worked, but ignored the issue of security (with the E-seal as a standalone seal), as the loads were not sealed by USCS.

4.3 ANALYSIS OF THE TECHNICAL EFFECTIVENESS OF THE SYSTEM

The E-seal evaluation assessed the system's ability to perform the functions as described in the Northwest International Trade Corridor Program Functional Specification document – TransCore's "blueprint" for system design and technical operations. The evaluation assessed the system's ability to detect tags, correlate container number and vehicle number; record vehicle number, container number, and departure time in the database; and perform other required data processing. Further, the evaluation investigated the crosscutting technical effectiveness of the E-seal technology based on the deployments of the USDA/Maersk Sealand E-seal application and USCS/Westwood application, and the TransCore/e-Logicity E-seal technical improvement effort.

The following four hypotheses were derived for this investigation:

- The system positively identifies the vehicle and container.
- The system reliably associates an E-seal container read with a truck AVI read.
- The system performs the functions described in the Northwest International Trade Corridor Program Functional Specification document.
- The system and its components have a low failure rate.

The measures of effectiveness, (MOEs), measures of performance (MOPs), and data sources for evaluating the hypotheses are presented in Table 4-3.

Table 4-3. Technical Effectiveness Evaluation Overview

Hypotheses	MOEs	MOPs	Data Source
The system positively identifies the vehicle and container.	Positive vehicle/ container identification.	Positive E-seal read.	TransCore System Statistics
The system reliably associates an E-seal container read with a truck AVI read.	Positive association of E-seal/AVI tags.	Positive E-seal/AVI tag association.	TransCore System Statistics
The system performs the functions described in the	System functional requirements.	The system requirements described in the Functional	TransCore System Statistics

Hypotheses	MOEs	MOPs	Data Source
Northwest International Trade Corridor Program Functional Specification.		Specification.	
The system and its components have a low failure rate.	Component failures.	Cause of component failure.	Component Documentation, Interviews, Failure Reports
	System failures.	Cause of system failure.	System Documentation, Interviews, Failure Reports

Based on the preceding information, and also noting the unique re-engineering of the E-seal that took place during this test, this technical effectiveness analysis is divided into the following subsections:

- 4.3.1 Identification of Vehicle and Container
- 4.3.2 Reading E-Seal Containers and Association with Vehicle Information
- 4.3.3 Verification Functional Specification
- 4.3.4 Technical Effectiveness of the Technology

4.3.1 Identification of Vehicle and Container

The TransCorridor Website (www.transcorridor.com) is the Northwest International Trade Corridor and Border Crossing System's means for displaying and sharing information. Numerous examples showing information that "the system positively identifies the vehicle and container" have been transmitted from the TransCorridor server and displayed one the Website. To illustrate one such instance, a sample of information for one Shadow Lines truck and container is shown in Table 4-4.

Table 4-4. Activity Information for Blaine USCS Northbound Exit

Blaine USCS: Northbound Exit **Friday, August 02, 2002 11:17:48 AM**				
Unit Number	Carrier DBA Name	Container (E-seal)	Lane	Passing Date Time
1533	Shadow Lines	WSTU747595	3	8/1/02 5:00:33 PM

In this case, the TransCorridor Website displays activity information for vehicles passing through the Blaine USCS Northbound Exit into Canada on Friday, August 1, 2002. The reader at the Blaine Exit read Shadow Lines truck 1533 with corresponding Container WSTU747595 passing through at 5:00:33 p.m.

Additional truck information can be accessed and viewed from the TransCorridor Website. For example, clicking on the highlighted Unit Number (1533) or Container ID (WSTU747595), opens a window to display vehicle data, container data, and recent event history. Table 4-5 shows a sample of recent event information for Vehicle 1533.

Table 4-5. Recent Event Information for Vehicle 1533

Vehicle Data	
AVI Agency, Tag ID	WA, 20876BA4
Carrier Company Name	Mountain Pacific Transport Ltd
Carrier DBA	Shadow Lines
Unit Num, Make, Year	1533, , 1998
Cntry, Jur, Plate, VIN	CA, BC, P51210, 1FUYSSEB2WP901642
Carrier Registrations	USDOT: 141514, CANSC: , MXDOT
ICC Numbers	
Safe / Legal	Rating: S, Safe: Y, Legal: Y, Permit: Y, License: Y
Container, In-Bond, Agent	
Mechanical Seals	WSTU747595-5, , APL
Electronic Seal	, , ,
Gross Weight (Lbs)	, Tampered: N
Location, Lane, Time	10058
Status	APL Exit Gates, 14, 8/1/02 2:42:25 PM
	Containers: 1, Target: N, Late: N, HazMat: N, Exit: Y
Container Data	
Container, In-Bond, Agent	WSTU747595-5, , APL
Mechanical Seals	, , ,
Electronic Seal	, Tampered: N
Gross Weight (Lbs)	10058
Location, Lane, Time	APL Exit Gates, 14, 8/1/02 2:42:25 PM
Status	Containers: 1, Target: N, Late: N, HazMat: N, Exit: Y

Recent Event History

Location	Vehicle Tag	Container (E-seal)	Lane	Passing Date Time
Blaine Exit	20876BA4	*WSTU747595*	3	8/1/02 5:00:33 PM
Blaine Approach	20876BA4	*WSTU747595*	1	8/1/02 4:56:28 PM
APL Exit Gates	20876BA4	*WSTU747595*	14	8/1/02 2:42:25 PM
APL Exit Gates	20876BA4	*WSTU747595*	14	8/1/02 2:39:14 PM

As displayed in Table 4-5, recent event information includes Vehicle Data information about the AVI tag, Carrier/vehicle characteristics, and registrations. Also available for viewing are indicators for the vehicle's safe/legal ratings.

The Container Data section shows container-specific information. Container seal status, gross weight, location, and status indicators can be reviewed. (Had an E-seal been attached to the container, the E-seal ID and status would also be shown.)

Recent Event History shows the location, lane, and date/time a vehicle tag and container were read. For each vehicle, the Recent Event History contains a log of recent vehicle/container activity. For example in Table 4-5, vehicle 1533 (Vehicle Tag 20876BA4) with container WSTU747595 passed two APL Exit Gate readers on 8/1/02 at 2:39:14 p.m., and 2:42:25 p.m. The next AVI tag read for the vehicle and container occurred at the Blaine Approach on 8/1/02 at 4:56:28 p.m. Finally, the vehicle and container passed the Blaine Exit reader on 8/1/02 at 5:00:33 p.m.

4.3.2 Reading E-Seal Containers and Association with Vehicle Information

Three tracking tests were conducted during the past year to investigate the ability of the TransCorridor system to read E-seal containers. The first of these tests, conducted by USDA and Maersk Sealand, began on December 18, 2001. The USDA/Maersk Sealand test was successful in identifying challenges that affect the ability of the system to read E-seals entering the Maersk Sealand shipping terminal in Tacoma, Washington, and proceeding on to the Blaine Northbound Exit.

A second test, conducted by the USCS and Westwood Shipping began on May 22, 2002, and lasted for 6 weeks. The USCS/Westwood test also provided useful results and insights into E-seals attached in Japan, passing through the APL shipping facilities in Seattle, Washington, and proceeding on to the Blaine Northbound Exit.

The third test, conducted by the TransCore and Shadow Lines, began and ended on June 26, 2002. This test demonstrated that the system correctly identifies and correlates vehicle information with container and E-seal information.

The results from all three tests have helped developers and participants identify logistical difficulties (such as installation/programming of the E-seal) and current operational limitations (e.g., only one of the four lanes at Blaine had a reader). Descriptions of the three tests are summarized in the following subsections.

4.3.2.1 USDA/Maersk Sealand Test

USDA has been intermittently attaching E-seals to containers at the Maersk Sealand shipping terminal in Tacoma since December 18, 2001. These in-bond shipments of produce were bound for Canada via the Blaine Northbound Exit. For each shipment TransCore was notified by email, and the TransCorridor Website was monitored while waiting for E-seal detection at the Blaine Exit. If an E-seal was not detected at Blaine, USDA verified that the vehicle crossed into Canada and TransCore reviewed the system logs to investigate if any system issue could explain why the E-seal was not being read.

Through July 30, 2002, a total of 47 E-seal containers were tested. Of the 47 tested, 25 were successfully read and 22 were not read at the Blaine Northbound Exit. However, 13 of the 22 unsuccessful readings occurred early in 2002 prior to a software upgrade and the identification of significant operational issues. These operational issues included difficulties in logistical procedures (E-seal installation/programming) and current operational limitations (only one of four lanes at the Blaine Exit had a reader).

These operational issues were corrected in the second portion of Maersk/USDA test, which was conducted between August and December 2002. Here, 28 of 28 E-Sealed containers (100 percent) were successfully read by USDA inspectors.

4.3.2.2 USCS/Westwood Test

This test consisted of installing E-seals at the Westwood facility in Japan. Beginning the week of May 20, 2002, Westwood shipped five E-sealed containers per week for 6 weeks through the Port of Seattle at APL's terminal. Each E-seal was programmed with the corresponding container number. After the containers arrived at the APL shipping terminal in Seattle, USCS officers used hand-held readers to verify the identification of trade transaction, container number, and the security of the E-seals. Next, the TransCorridor Website was monitored to determine if the Blaine USCS Northbound Exit reader detected the containers and E-seals.

Figure 4-3 shows the number of E-seals read (by week) during the 6-week test. Out of 30 E-seal containers, 24 were successfully detected. A new version of the Northwest International Trade Corridor Operations System software was installed during the last 2 weeks of testing and 8 of 10 E-seals were read at the Blaine Exit. During the last week, one E-seal was completely unreadable at the APL facility (and at the Blaine USCS Northbound Exit) and the second E-seal was not read at the Blaine Exit.

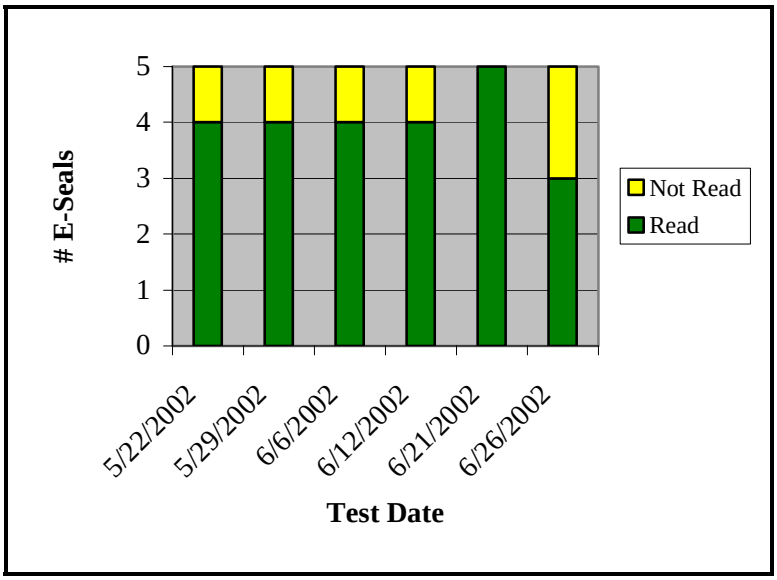
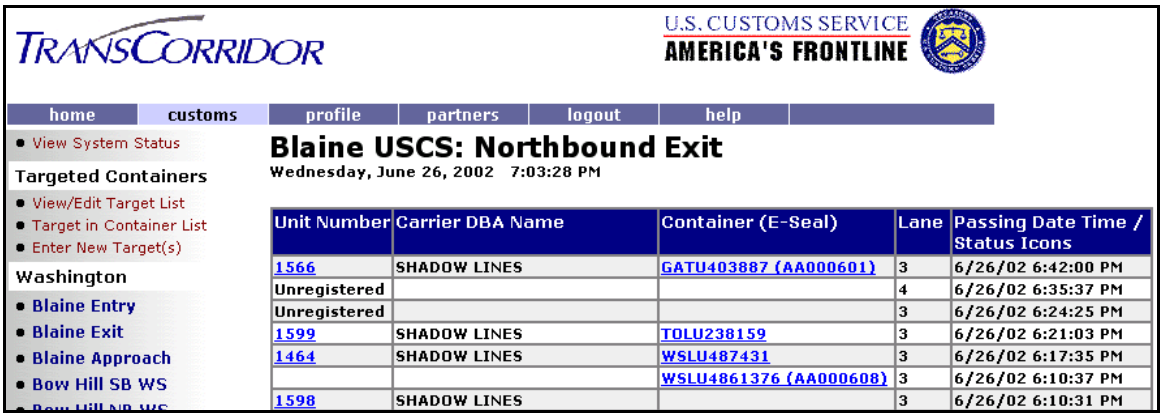


Figure 4-3. E-Seal Reads During the Initial 6-Week Period of the USCS/Westwood Test.

It should be noted here that these operational issues were corrected in the second portion ("Round 2") of the USCS/Westwood test, which took place over the summer of 2003. Here, 28 of 28 E-Sealed containers (100 percent) were successfully read at the Blaine USCS station.

4.3.2.3 TransCore/Shadow Lines Test

The TransCore/Shadow Lines test was conducted on June 26, 2002 to verify if vehicle information is correctly correlated with container and E-seal information when read at the Blaine Northbound Exit. At 6:42:00 p.m., a single Shadow Lines vehicle (Unit # 1566 – Tag #20876BC1) passed through the Blaine Northbound Exit and successfully demonstrated that the system correlated the vehicle to a container (GATU403887) with an attached E-seal (AA000601). Depicted in Figure 4-4, the E-seal was detected at the Blaine Exit and all vehicle, container, and E-seal information were correctly displayed on the TransCorridor Website.



Unit Number	Carrier DBA Name	Container (E-Seal)	Lane	Passing Date Time / Status Icons
1566	SHADOW LINES	GATU403887 (AA000601)	3	6/26/02 6:42:00 PM
Unregistered			4	6/26/02 6:35:37 PM
Unregistered			3	6/26/02 6:24:25 PM
1599	SHADOW LINES	TOLU238159	3	6/26/02 6:21:03 PM
1464	SHADOW LINES	WSLU487431	3	6/26/02 6:17:35 PM
		WSLU4861376 (AA000608)	3	6/26/02 6:10:37 PM
1598	SHADOW LINES		3	6/26/02 6:10:31 PM

Figure 4-4. TransCore/Shadow Lines Test Information Displayed on the TransCorridor Website.

4.3.3 Verification of the Functional Specification

A list of the system functional requirements were derived from the Northwest International Trade Corridor Program Phase Two Washington-British Columbia Cross-Border Commercial Vehicle Operations Functional Specification dated November 15, 2001. Each system requirement was verified based on observations, information obtained from the TransCorridor Website, and discussions with TransCore staff.

Table 4-6 shows the results of this investigation. Based on the system requirements, the system appeared to function as specified. Additional clarifying information is included in the Notes column.

Table 4-6. Results of System Requirements Verification

System Requirement	Result	Notes
(2.2.0-1) The system shall detect registered transponders (TDMA Tags) mounted in windshields of participating Vehicle (Power Unit) at selected entry gates at participating Sea Port Shipping Agent's facilities.	Yes	Entry gates currently only at APL Seattle.
(2.2.0-2) The system shall receive Container ID, In-bond number, Carrier & Unit number, from participating Trucking Agent's IMS, when the truck departs the Vancouver area.	Yes	Email and/or Web data entry form provided for any trucking agent. Shadow Lines is the only carrier currently identified, and it is waiting for computer installations before it begins regular use of this feature. Commercial driver license number for driver can also be entered.
(2.2.0-3) The system shall correlate Carrier & Unit number with truck's TDMA Tag (Truck ID).	Yes	This is true for all registered vehicles (currently about 90 in the database).
(2.2.0-4) The system shall record Transponder Serial Number, Carrier/Truck ID, Container ID, In-Bond Number, and USCS facility departure time in the database.	Yes	Also true for all sensor locations.
(2.2.0-5) The system shall detect TDMA Tags mounted in windshields of participating trucks at Bow Hill traveling in both Northbound & Southbound directions on I-5.	Yes	Also at Cle Elum WB, Fort Lewis NB, Ridgefield NB, and Stanwood Bryant NB. Bow Hill NB is currently shutdown pending a software update from IRD Corporation.
(2.2.0-6) The system shall record Transponder Serial Number and time detected at Bow Hill North & South.	Yes	See 2.2.0-5 above.
(2.2.0-7) The system shall detect TDMA Tags mounted in windshields of participating trucks entering USCS Commercial Vehicle Facility at Blaine POE heading South.	Yes	Operational as of 6-18-2002.
(2.2.0-8) The system shall record Transponder Serial Number and time entering USCS Commercial Vehicle Facility at Blaine POE heading South.	Yes	
(2.2.0-9) The system shall obtain Container inspection/preclearance indicators from CCRA.	Yes	This feature is provided for, but CCRA has yet to participate. Phase 2 offers an interface to CCRA only so that they can evaluate what services they may want in the future.
(2.2.0-10) The system shall present CCRA with an alert for registered and tagged trucks and their associated containers that are heading into Canada, from the US.	Yes	They have access to current activity at both the Blaine approach and exit locations that immediately precede the CCRA

System Requirement	Result	Notes
		Pacific Highway facility.
(2.2.0-11) The system shall notify CCRA of trucks and associated containers approaching Canada, indicating their status of inspection/ pre-clearance indicators for the container associated with this truck/container.	Yes	See 2.2.0-10 above.
(2.2.0-12) The system shall notify CCRA of In-Bond containers entering Canada from the US.	Yes	See 2.2.0-10 above.
(2.2.0-13) The system shall provide Internet Web-based access to CCRA and participating Trucking Agents.	Yes	The TransCorridor Website is the primary interface for Trade Corridor information. Access to this site can be granted to any interested party upon approval.
(2.2.0-14) The system shall provide Web displays to CCRA of containers that have exited to the US from Canada's Pacific Highway Customs Facility to the USCS Commercial Vehicle Facility at Blaine POE today.	Yes	CCRA also has access via the website to the Blaine Southbound Entry location for this information.
(2.2.0-15) The system shall provide Web displays to CCRA of In-bond containers that are currently approaching USCS Commercial Vehicle Facility at Blaine POE from the South and heading for the Canadian Pacific Highway Customs Facility (approaching US POE from South).	Yes	This is essentially the same as 2.2.0-10. The Blaine Approach location is available to CCRA on the Website.
(2.2.0-16) The system shall provide Web displays to CCRA of containers that are at USCS Commercial Vehicle Facility at Blaine POE and entering the Canadian Pacific Highway Customs Facility (exit from US into Canada).	Yes	This is essentially the same as 2.2.0-10. The Blaine Exit location is available to CCRA on the Website.
(2.2.0-17) The system shall provide a web display to allow CCRA to enter a list of Northbound containers to be targeted by CCRA for inspection when they arrive at the Canadian Pacific Highway Customs Facility from the US.	Yes	See 2.2.0-9 above.
(2.2.0-18) The system shall detect E-seals on selected containers at the USCS Commercial Vehicle Facility at Blaine POE North Exit and correlate the E-seal numbers with associated container Ids.	Yes	Provided the container number is programmed in the E-seal.
(2.2.0-19) The system shall provide Activity Reports to participating Sea Port Shipping Agents, Trucking Agents, USCS, CCRA.	Yes	Current activity reports are now available to all authorized users. Activity history will be added in the near future.
(2.2.0-20) The system shall detect TDMA Tags mounted in windshields of participating trucks at Port Mann Weigh Station traveling East (option 1) or at the Pacific Weigh Station traveling North (option 2).	Yes	All software is in place to handle data from the Port Mann location when it opens. Plans for a system at the Pacific Highway Weigh Station have been canceled.
(2.2.0-21) The system shall record Truck ID and	Yes	The Port Mann Weigh Station will

System Requirement	Result	Notes
time detected at Port Mann or Pacific Station.		be part of the WSDOT CVISN system. WSDOT has an email interface to add new locations and send detection event reports for those locations as they current do for the 6 existing weigh station locations.
(2.2.0-22) The system shall provide for receiving & maintaining updated truck/ container weight/time data in the database.	Yes	The database has fields for all of this data. The shipping terminals currently provide weights for containers, but the weigh stations do not currently provide any weight data. The interface does exist to exchange and store detailed weight information if WSDOT chooses to provide such information in the future.
(2.2.0-23) The system shall provide web page displays incorporating weight/time data for use by the Port Mann Weigh Station (option 1) or the Pacific Weigh Station (option 2).	Yes	This feature is provided for any weigh station that wishes to provide such information. However, WSDOT does not currently send weights – only vehicle tag ID, time and location.
(2.2.0-24) The system shall receive registration reports from WSDOT CVISN and Canadian ICBC systems, providing the TCOS database with Carrier/Vehicle ID, associated Transponder Serial Number, and Safe & Legal status indicators for operations in the specific jurisdiction.	Yes	WSDOT currently updates the TCOS vehicle registration list once every week using an email interface. WSDOT CVISN also includes ICBC vehicle lists.
(2.2.0-25) A Weigh Station system shall be installed, at the Port Mann Weigh Station, to weigh and identify commercial vehicles using Weigh In Motion Scales and AVI technology (option 1).	Yes	Please contact Ed McCormack at WSDOT via e-mail or phone (edm@u.washington.edu, 206-543-3348) for a schedule for the opening of the Port Mann Weigh Station.
(2.2.0-26) The Weigh Station system shall verify vehicle movements by a tracking system to ensure compliance with direction to report (option 1).	Yes	This is the Compliance Reader feature of the IRD Weigh Station Bypass system.
(2.2.0-27) The Weigh Station tracking system shall consist of an additional AVI location on the mainline lanes adjacent to the scale house, as well as in-road sensors to detect passing commercial vehicles (option 1).	Yes	See 2.2.0-26.
(2.2.0-28) The Weigh Station system shall trigger an alarm to the station operator for any commercial vehicle passing without a valid transponder, or with a transponder by which they were directed to report (option 1).	Yes	See 2.2.0-26.
(2.2.0-29) The Weigh Station system shall facilitate an option that may be incorporated to include over-height detection sensors at the	Yes	This option is available from IRD. However, this option has been declined at this time for the Port

System Requirement	Result	Notes
mainline WIM. The sensor will be set at the legal allowable height limit for operation on Highway 1. If a vehicle is detected exceeding this height, it will be identified as a warning in the system, and may be reason for having the vehicle report to the station, depending on the operational settings (option 1).		Mann Weigh Station.

4.3.4 Technical Effectiveness of the Technology

The following two subsections provide an overview of the general factors concerning the technical effectiveness of the system, and an analysis of the unique technical challenge that was overcome concerning the original design of the E-seal system.

4.3.4.1 System Technical Effectiveness Overview

Interviews with TransCore developers and findings from the three E-seal tests provided tremendous insight into the technical issues and improvements related to the E-seal components and TransCorridor system. During this deployment there were several challenges and obstacles that had to be overcome. The following briefly describes a few of the highlights.

- **Communication Difficulties.** Although the E-seal program procedures were well documented and distributed to all participants, when it came to the actual process, there appeared to be some breakdown in the communication channels. Truck drivers were reporting that when they approached the border they encountered staff who did not understand why they were stopping. Prior to this change in procedure, shipments with electronic bonds had not been required to stop, so it took a few months for everyone to adjust to the new process. The small number of E-seals installed in a given week also contributed to confusion about the procedures.

- **Technical Difficulties.** Although there has been no conclusive evidence that any physical E-seals were defective, some appeared to have failed to be read due to improper installation. The E-seal consists of a small plastic transponder box and a metallic spike with a plastic-coated head. The metallic end of the spike must be firmly and completely inserted into the transponder in order to engage the internal battery and activate the transponder. The transponder then remains active (transmitting three times per second) until the battery runs out, the transponder is destroyed, or the spike is cut. Unfortunately, the spike can be inserted to hold without being fully engaged. Shortened battery life was observed after several months of continuous operation. The E-seal installation procedure was updated to resolve this issue. The E-seal installer programs the E-seal with the container numbers using a hand-held E-seal programmer/reader. This hand-held unit is now used to read the E-seal and verify its programming **after** the E-seal is secured to the container. If this fails, more force is used to engage the spike. No failure of an E-seal has been reported since this procedure has been implemented.

- **Additional Readers Required.** There is currently only one E-seal reader deployed at the Blaine Northbound Exit. This reader is only in one lane of a 4-lane sign bridge at the exit into Canada at the USCS commercial vehicle border crossing facility at Blaine, Washington. This reader is capable of reading E-seals in the other lanes, but it is only tuned for the one lane. Additional E-seal readers and/or antennas to fully cover the other exit lanes and the bypass lane will be required to increase the reliability of the E-seal system at Blaine. E-seal readers to fully cover the exits at the shipping terminals (APL and Maersk Sealand) will also be required to automate the monitoring of containers through the United States using E-seals alone.

- **Server Challenges.** Throughout the system development period a variety of server-related challenges occurred. The original TransCorridor server software was down an average of once a week during the E-seal testing period (between December 2001 and June 2002). The server has not been down once since the installation of the new software on June 18, 2002. These down times were each a few hours in duration, usually overnight before being resolved and/or reset in the morning. Over the Christmas to New Year's break, however, the engineers were all out of the office, and the server was down for 5 days.

- **Software Challenges.** While the server was down, the original TransCorridor software appeared to have lost most of the accumulated event information. In actuality, the data remained in site log files, but could not be successfully transmitted to the TransCorridor central database for display on the Website. The new TransCorridor software can buffer data at the sites for days if the server is inaccessible for any reason, and still successfully transmit the data when the server comes back online. The original TransCorridor server down times were partially caused by intermittent software-related problems that resulted in the server software lockups. These challenges have been resolved with the new software implementation.

- **Other System Challenges.** Other system challenges included: interruptions in Internet ISP service; an expired domain name; telephone lines severed at the Blaine site by maintenance personnel; ISDN telephone service discontinued due to excessive bills; site software lockups; and site dial-in access lockouts. The site-related challenges under TransCore's control have been resolved with the new TransCorridor site software. All of the ISDN lines will be replaced with DSL in the next few weeks as a cost-cutting measure.

4.3.4.2 TransCore/e-Logicity E-Seal Technical Improvements

A major technical improvement was made to improve system performance. Early in the FOT the system integrator (TransCore) and the E-seal vendor (e-Logicity) successfully worked together to overcome a significant technical hurdle in the implementation of the technology. Following is a description of the technological challenges and the accomplished improvements.

In late 2000, TransCore completed an engineering evaluation of the prototype E-seal and determined that it would not perform adequately in a roadway environment. Because of limited signal strength and pauses between transmission periods, an

E-seal read either required trucks to stop or need to deploy an extensive array of antennas. Neither option was viable for this roadway-oriented project, since the first option required a dedicated roadway and the second option was expensive. Based on the TransCore test, e-Logicity agreed to modify the E-seal for use in this FOT.

In mid-2001, TransCore received the first prototype of the redesigned E-seal. The modification involved increasing the E-seal's power so that reads can occur while the vehicle is in motion. In examining TransCore's test of the redesigned E-seal, transmission pulses with a sweep of 10 and 50 seconds with both E-seals located 10 feet from the antenna produced the following results as depicted in Table 4-7.

Table 4-7. Transmission Intervals of Original and Newly Re-Designed E-Seals

E-Seal	Time #1	Time #2	Time #3	Time #3
Original	4 sec	7 sec	4 sec	3 sec
New	0.8 sec	0.6 sec	0.3 sec	0.3 sec

These preceding results indicate that the broadcast rate of the new E-seals increased by a factor of 10 over the original E-seal. TransCore's next step was to test the E-seals in a roadway environment. TransCore deployed a side-mounted antenna fixture attached to an aluminum tripod stand at the side on a 3-lane city street near its office complex in San Diego, California. The antennas were placed approximately 20 feet from the nearest traffic lane while testing. A truck and container drove from left to right at varying speeds of 25, 35, and 45 MPH past the antenna position in the near lane and returned in the opposite direction in the far lane. The distance from the antennas to the edge of the far lane was approximately 48 feet. The results of this test from both directions are shown as follows in Tables 4-8 and 4-9. A "Pass" indicates that the E-seal mounted on the container was successfully read as the truck hauling it drove past the antenna.

Table 4-8. E-Seal Transmission Test – Distance from Lane Edge = 20 feet.

Speed (MPH)	Attempt #1	Attempt #2	Attempt #3	Attempt #4
25 MPH	Pass	Pass	Pass	Pass
35 MPH	Pass	Pass	Pass	Pass
45 MPH	Pass	Pass	Pass	Pass

Table 4-9. E-Seal Transmission Test – Distance from Lane Edge = 48 feet.

Speed (MPH)	Attempt #1	Attempt #2	Attempt #3	Attempt #4
25 MPH	Pass	Pass	Pass	Pass
35 MPH	Pass	Pass	**Fail**	Pass
45 MPH	Pass	Pass	Pass	Pass

In these tests, the E-seal was read in all but one instance. It is possible that the E-seal was not read in that one instance due to traffic in the near lane.

Following this successful test, the E-seal deployment, which had been delayed nearly a year, was back on track. This experience illustrates both the unexpected technical problems that can develop during these intermodal freight technology FOTs, as well as the importance of successful cooperation and persistence of the system integrators and vendors in deploying these technologies.

5. CONCLUSIONS, AND RECOMMENDATIONS

This section presents the conclusions and recommendations developed by the Evaluation Team based on data analyzed and the lessons learned in the design and implementation of this intermodal freight ITS field operational test. The conclusions highlight "lessons learned" from the presented analyses, and the recommendations provide suggestions to be considered in subsequent tests of this technology.

5.1 CONCLUSIONS

Following are the conclusions that were developed by the Evaluation Team, organized across the following five categories:

- 5.1.1 Conclusions – System Operations
- 5.1.2 Conclusions – Technology
- 5.1.3 Conclusions – Institutional Challenges
- 5.1.4 Conclusions – Stakeholder Participation
- 5.1.5 Conclusions - Security

5.1.1 Conclusions – System Operations

Overall, the system operations for both supply chains tested in this effort performed well, considering the system was the first prototype E-seal system tested in an operational environment within the United States. While the initial E-seal read rates were only adequate in the early months of the test, in the latter months, the system had approached a near 100 percent read rate, thus validating the E-seal operational concept. For future E-seal deployments, this test showed that efficiencies in E-seal read rates can be improved. These efficiencies were based on improved familiarity and use of system procedures by truck drivers and installers, and by a more comprehensive deployment of E-seal readers/antenna infrastructure elements at the key read points.

In regard to the E-seal read rates, the USDA/Maersk Sealand supply chain test resulted in 47 E-seals being coded and deployed, with 53 percent being read at the border. Once the operational and training issues were resolved here, the read percentage increased to 100 percent for latter portion of this test, with 12 out of 12 E-seals being successfully read. Correspondingly, in the spring of 2002, the USCS/Westwood test initially resulted in 30 E-seals being coded and deployed, with 80 percent being read at the border, and only 10 percent showing a "tampered with" read at the Port of Seattle. Once the operational and training issues were resolved here, the read percentage increased to 100 percent for latter portion of this test, with 28 out of 28 E-seals being successfully read.

In regard to the infrastructure deployed in this test, while this operational test developed and deployed a system with all the necessary components, it is not a complete infrastructure that could support fully deployed operations. For example, E-seals were installed at the Port of Tacoma and Japan, with reads occurring at the Blaine border crossing; however, there are no stationary readers at the port gates or along I-5 between the Seattle/Tacoma region and the border.

In addition, while it was anticipated that a few of the E-seals would be linked to a transponder and thus tied into the existing AVI network, this did not occur due to a limited set of E-seals tested versus the small set of AVI-equipped trucks operating in the region. This incomplete infrastructure made it difficult to evaluate the tracking function benefit for the shippers/receivers.

With the USCS/Westwood test, the shipper and receiver were shielded from the test as time did not permit bringing them into the project. USDA indicated a preference for being able to view a more complete network of readers for their operation, and Westwood needed better tracking capabilities to sell the system to its customers.

5.1.2 Conclusions – Technology

Overall, the disposable E-seal technology performed well during the latter stages of the FOT after a number of technical hurdles were overcome. As the FOT began, the original E-seal design faced challenges with broadcast speed being too slow to read moving trucks. Through cooperative efforts between the system integrator and the E-seal vendor, overcoming this technical challenge was one of the early successes in this FOT. In addition, as USDA began using the E-seals, staff encountered faulty E-seals and/or E-seals that were extremely sensitive – which could easily become identified as being “tampered with” during the installation process. However, the system integrator (Transcore) and E-seal vendor (e-Logicity) expressed confidence that this problem could be overcome in follow-on versions of this system.

The e-Logicity E-seal, which is now being manufactured and marketed by E.J. Brooks, proved the technology concept that a low-cost disposable electronic container seal could be developed for the intermodal freight industry. However, some technical challenges must be addressed before full deployment of this particular E-seal system can occur. Chief among these technical challenges is the E-seal’s operating frequency – that of a Department of Defense (DoD) frequency (315 MHz) that would need to be changed under a full deployment scenario. Additionally, neither of the potential operating frequencies of this E-seal (315 MHz and 433.92 MHz) is compatible with CVISN AVI truck transponder technology. Using this E-seal in one of its current operating designs will require that many facilities serving the ITS freight community would have to deploy dual infrastructure elements (readers, antennas, etc.) for both E-seal and AVI technologies.

In terms of the hand-held reader technology, the readers proved difficult for users, who had to navigate through a cumbersome series of menus. Also, in its current design, the reader is not able to automatically populate the E-seal number field by obtaining that number from the E-seal itself. Additionally, the battery life of the hand-held units was inadequate for this test and should be lengthened. And finally, there was no wireless

method available for the reader to connect to a computer for direct upload to the TransCorridor system.

As described, the overall system was developed and deployed successfully. However, as lessons were learned, participants were able to identify possible improvements to the system to achieve a more operationally friendly system. These ideas included more fully completed infrastructure deployments, software modifications, and communication mechanisms. This process began with the system developers working together to integrate the various components, and ended with the support provided to the participants once the system was deployed.

5.1.3 Conclusions – Institutional Challenges

USDOT and WSDOT worked successfully over the 2.5-year period of this FOT to keep the project on track despite considerable challenges. The overall project schedule was heavily impacted by technological and operational constraints. The technology had to be re-engineered to operate effectively. Deployment was further delayed as Maersk merged with SeaLand and had to subsequently withdraw from the test for 9 months. WSDOT, supported by USDOT, the Port of Tacoma, and others, continued promoting resolution for these factors, and in the end, resulted in developing and deploying a successful system, even though the deployment took a year longer than originally anticipated.

Additionally, communication was key to the success of this test. There were two separate and distinct types of communication involved here. The first type is the regional coordination and cooperation among freight and security stakeholders. The regional stakeholders remained interested and supportive of the program over a fairly lengthy deployment process. This ongoing, supportive coordination allowed multiple agencies to become more knowledgeable regarding the entire topic of international trade and border-crossing issues.

The second communication type occurred among specific project participants. This entailed coordination on system development and deployment, and communication among deployers and participants. This area was the most strained. Operations staff from USDA, USCS, Maersk Sealand, Westwood, and PRTI worked to establish their new operating procedures within the confines of the operational test, while maintaining their own daily business functions. While there were momentary lapses in effective communication, all such instances were recovered from and resulted in improved communication overall.

Finally, labor challenges have remained a hot topic throughout the course of this FOT, primarily because the marine cargo industry is heavily unionized. This has not been a showstopper, but it has been a continuously repeated theme as something that must be worked around and planned for in further development and deployment of future tests.

In addition, the motor carrier participants found some of the test requirements to be burdensome, as they created additional work, such as having drivers stop at Blaine for a manual inspection. Overall, the test required all participants to take on additional

responsibilities, which would need to be more carefully addressed under a full (or more complete) deployment.

5.1.4 Conclusions – Stakeholder Participation

The flexibility of the stakeholders participating in this test was a critical factor in its success. USDA and Maersk Sealand modified the initial procedures early in the test to accommodate initial read failures when 12 of the first 14 E-seals coded by the USDA were not read at Blaine. This was the result of several factors, including drivers using the wrong border crossing and the E-seals being incorrectly coded. This created an additional component to the process, which mandated that all trucks cross at Blaine and physically stop at USDA for a manual E-seal inspection. This action eliminated what would have been an automated shipment clearance process; however, based on USDA's reason for participation, it was critical that the load be cleared.

For USCS and Westwood, the flexibility was evident in the steps both entities took to make the test happen. Westwood undertook several activities to shield its customers from any disruptions and worked with a new motor carrier (as did USDA and Maersk Sealand) to ensure the test would occur within the time constraints.

In terms of stakeholder recruitment, WSDOT and other deployers worked continuously over the multiyear project to recruit the necessary participants at the appropriate time. This included taking advantage of the USDA/Maersk Sealand scenario, as well as bringing Westwood and USCS online very quickly.

In terms of stakeholder response to the technologies, the E-seal system and the specific deployment initiatives required participants to change their standard mode of operations. Detailed material was developed and distributed to all participants that clearly outlined the required activities. However, as with any change, affected staff were required to undergo a learning process to become comfortable with the new procedures. For example, truck drivers were reporting that when they approached the border, they encountered staff who did not understand why they were stopping, since electronically bonded loads are not required to stop. After a few months, the participants became comfortable with the new process. The low volume of E-sealed shipments on an infrequent basis made this a more time-consuming process than if 100 shipments were being processed every week. However, the USDA/Maersk Sealand operation became fully integrated into the participants' daily activities, and the USCS/Westwood operation became fully operational for the specified 6-week period.

Finally, one of the more critical obstacles in this test was developing a process that did not impact the operations and responsibilities of either the shippers or receivers. The transportation company participants agreed to test the system; however, it was critical to them that this willingness to participate did not result in any disruption to their customers. For example, in an effort to minimize interactions with customers, Westwood provided an agent to install the E-seals in Japan and instructed its truck drivers to cut off the E-seals after exiting the United States.

5.1.5 Conclusions – Security

While security was not considered the predominant goal of this test when it was first awarded in late 1999, the events on and following September 11, 2001 have caused major national attention to this test both within and outside USDOT. E-seals are now being reviewed by organizations such as the Cargo Handling Cooperative Program (CHCP) as perhaps the central in-the-field detection element in a future intermodal freight security system. The results of this test, while not focused in any major way on security, do provide input to the ongoing research and discussions of the federal government, CHCP, and others who are considering various E-seal technology options and architectures. The Applied Physics Lab at John Hopkins University is currently developing an "E-seal architecture" for USDOT; the results of this evaluation will provide direct input to this ongoing effort.

Correspondingly, cargo security has now become a major focus for the USCS. This action has pushed this E-seal FOT into the forefront as a possible full deployment scenario. USCS has plans to build on the USDOT-sponsored system with expansion into Canada for in-bond shipments to the United States. This expansion may include operations in Vancouver, Montreal, and Halifax. Additionally, a system using "trusted shippers" is currently being examined by USCS, with whose support this opportunity could materialize into a system that could promote security through E-seal technology.

A major concern with the disposable E-seal technology tested here is that the information is not real-time – the E-seal cannot broadcast a message that it has been tampered with unless it is in the proximity of a reader antenna. While this may help to reduce acts of pilferage on containers by later tracking when the container was opened, it does nothing to stop the potential corruption of a container with weapons of mass destruction (WMD) during shipment – in short, it would be too late. However, the cost of developing E-seals that could broadcast emergency tampering messages over cellular or satellite networks is currently viewed as prohibitive to the intermodal freight industry. However, the "good news" may be that if E-seals are just one point of security data in an overall intermodal freight security system, then this data can be integrated with other data in the system to provide for enhanced security against worst-case scenarios such as WMD smuggling. Such systems are currently being examined in the Federal Motor Carrier Safety Administration's Hazardous Material Transportation Safety and Security National Operational Test.

Another major security concern with E-seals revolves around the individual verifying the integrity of the shipment and activating the seal. The disposable E-seal technology investigated in this test allows for notifications to any breach in security but does not provide intelligence regarding the "actual" contents of the load. Such intelligence has been demonstrated in the USDOT's Electronic Intermodal Supply Chain Manifest FOT, which has been demonstrating electronic cargo manifests for the past 2 years for air cargo at Chicago O'Hare, JFK, LAX, and Toronto international airports.[7]

[7] See Jensen, Mark, Mike Williamson, et. al., "Electronic Intermodal Chain Supply Manifest Field Operational Test Evaluation Draft Final Report," prepared by SAIC for the USDOT, December 2002.

An additional concern with E-seals revolves around issues of an internationally universal communications frequency. At this time there is not a standard frequency that is reserved solely or these applications but there are groups within industries and governments that are working to find solutions to address the issue of standardized frequencies. Currently, Admiral Carl Seiberlich, of TranSystems Corporation, is coordinating United States' efforts to the E-seal international standards bodies. USDOT and USCS have the potential to play a major role in this international dialogue.

From a global perspective, E-seals and other technologies are being widely investigated for their potential effects upon worldwide container security. An interesting viewpoint of the current status of the movement of goods has been labeled "Wolfe's Paradox," which suggests that the "overall logistics systems capabilities are growing simultaneously more robust and more fragile."[8] For example, sophisticated JIT (Just-In-Time) logistics supply chains that rely on ports and intermodal terminals as "virtual warehouses" may be more subject to security vulnerabilities than older, less efficient logistics models that involved secure storage and maintenance of goods prior to delivery.

The Wolfe Paradox demonstrates the need for security applications to be both capable and operationally efficient. E-seals may have the potential to allow for greater visibility and accuracy within current logistics supply chains. If an E-seal can demonstrate the ability to provide a value added feature through tracking or automated clearance, the odds of success will be greatly improved. The paradigm associating security with decreased efficiency must be reassessed to read: "How can security and efficiency combine to satisfy the needs of shippers, carriers, and the government."

5.2 RECOMMENDATIONS

The Evaluation Team offers the following recommendations based on the evaluation analysis of performance, project documentation, results, and conclusions regarding the E-seal system as submitted within this final report:

- **Increase Tracking Capability.** The infrastructure should be further developed to have additional E-seal fixed readers and/or antennas on all exit lanes and the bypass lane or a link to the existing AVI/transponder system. Either way, reads need to be taken at the port of departure, along I-5, in advance of the border, and at the border. E-seal readers to fully cover the exits at the APL and Maersk Sealand shipping terminals would automate the monitoring of E-seal containers traveling domestically through the United States.

- **User-Friendly Equipment.** E-seals should be re-engineered to work on an accepted frequency and should be made more user-friendly for coding. The e-Logicity E-seal currently in use is somewhat complicated to program and install,

[8] "Freight Transportation Security and Productivity," Executive Summary, prepared by Michael Wolfe of the North River Consulting Group for the USDOT, April 2002.

and its operating frequency is under a temporary waiver from the FCC that will soon expire. In an effort to remedy this situation, e-Logicity has already developed a next generation E-seal, which should be reviewed and tested for possible use and/or further refinement. In addition, the technical feasibility of making the E-seals readable by AVI readers should be investigated to make it CVISN compatible.

- **Improve Reader Functionality.** The hand-held E-seal readers should be re-engineered to improve their functionality. They should be simplified to provide the specific activities required for this operation. This would facilitate E-seal coding as fewer menus result in less manual interaction. In addition, the reader should automatically populate the E-seal number field by obtaining that number from the E-seal itself. The battery life of the units was inadequate for this test and should be lengthened. And finally, an easy way for the reader to connect to a computer for direct upload to TransCorridor should be developed (potentially wireless). From an operational perspective, participants should have multiple hand-held units in the future to better manager instances when a unit is nonfunctioning.

- **Initial Data Entry.** Point of origin E-seal data should be entered (manually or automatically) into the TransCorridor system as the first of several load-specific data points. These data were available manually as part of this test, but were not entered into the system.

- **More Complete Infrastructure Prior to Testing.** A more complete infrastructure should be deployed to better test the feasibility of full deployment. This test proved that the technology worked and feedback has been obtained from the participants. Most participants commented that full deployment is the only way to really quantify the benefits. A next phase of this system should address these issues.

- **Increase Number of Participants.** The number of participants should be expanded in future applications to test the system with a larger volume of entries. Just over 100 E-seals were coded and put through this system. The test was successful; however a larger number of E-seals should be tested in a more complete infrastructure to validate the statistical significance of these initial findings.

- **CVISN Compliance.** The entire E-seal system should be reviewed for CVISN compliance. Currently, the system is not compliant and becoming compliant would expand its functionality by using the existing ITS infrastructure throughout the United States.

- **Include Other Border Crossing Activities.** Other border crossing activities (such as INS) should be reviewed and included in future tests to investigate the potential for a truly automated clearance program for commercial vehicles.

- **Implement a Border Enforcement Procedure.** A border enforcement procedure should be defined and developed to address any E-sealed loads that appear to be “tampered with” upon reaching Blaine. This is an important component because within a mile of passing the fixed reader, the truck enters Canada, thereby leaving United States’ jurisdiction. This could be addressed in several ways. Two possible ways include:

- Reciprocity agreements with Canadian law enforcement officials to where they would have access to the TransCorridor system and be responsible for apprehending the vehicle; and

- Developing a red/green light system in advance of the border that requires any "tampered" loads to stop for inspection.

- **Begin the Challenging Effort of Integrating E-Seal Technologies and Other Government-Sponsored Security Technologies.** The "Surface Transportation Vulnerability Assessment" developed by the John A. Volpe National Transportation Systems Center states that "each of these technological applications (ITS technologies) also brings with it a corresponding new or increased vulnerability." Thus, there is a concern on the over reliance of a single system such as an E-seal system, which has no duplication for secondary security checks. With this in mind, any technology that is implemented to increase security will have to be fully supported and work with other systems to ensure that the integrity of shipments must be verified through multiple checks.

  From a governmental point of view, these verification checks need to be internalized as well – where relevant, disparate government systems under development such as the E-seal System Architecture effort and the USCS Automated Commercial Environment (ACE) program, must be able to share information in order for a national freight security system to be successful. If will thus be critical in coming years for the USDOT, U.S. Department of Homeland Security, USCS, CHCP, IFTWG, private industry, state DOTs, and others to work together to integrate currently disparate systems to support common needs for improved national security and improved industry efficiency though intermodal freight technologies.

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APPENDIX A: SAMPLE SURVEY QUESTIONS

Questions for WSDOT Institutional Challenges & Customer Satisfaction

Background Information:

- Information about the respondent (job title, responsibilities, etc.).
- Information about the company (name, type of business, number of employees, number of shipments per year).
- Information about business practices (method of arranging/confirming pickup/ delivery, shipment tracking, manifest preparation, etc.).

Interview Questions:

The impact of the FOTs on interagency coordination

- Did the FOT improve interagency information sharing?
- Has the FOT facilitated coordinated planning and operations?
- Did differing objectives between participating agencies pose challenges? How were they overcome?
- Did you obtain support from policy makers and upper management? How did you obtain their support and buy-in?
- Has trusting relationships between upper management, decision-makers, and/or policy makers developed from the FOT? What impact will this have on future activities?
- Were roles and responsibilities clearly defined? How were roles assigned? Who had what roles?

Impact of the FOTs on Public/Private Coordination:

- Did the FOT improve public/private information sharing?
- Has the FOT facilitated coordinated planning and operations?
- Did differing objectives between participants pose challenges? How were they overcome?
- Did you obtain support from policy makers and upper management? How did you obtain their support and buy-in?
- Has trusting relationships between upper management, decision-makers, and/or policy makers developed from the FOT? What impact will this have on future activities?
- Were roles and responsibilities clearly defined? How were roles assigned? Who had what roles?
- Were specific incentives identified/used to encourage private sector involvement? What were they and why?
- Should any regulations, policies, or procedures be changed to facilitate private sector involvement?

Challenges to the Development of Information Sharing Agreements:

- What were some of the challenges to establishing information-sharing agreements?
- How were they overcome?
- How long did it take?
- What challenges were not resolved?

Survey: Questions to be Addressed:

Identify Perceived Benefits for the Users:

- What was the impact of having the seals installed in Tacoma vs. abroad?
- Was the system useful for logistics?
- Was the system useful for management of transportation resources?
- Overall, are you satisfied with the system? Why?
- How was the system especially useful?
- What were the benefits to using the new system?
- What were the drawbacks to using the new system?
- Did the system provide timely information?

Identify User Acceptance of the ITS Systems

- Do you feel comfortable using all system features and capabilities?
- How often do you use the system?
- Was the system helpful?
- What was your favorite feature?
- What was your least favorite feature? Why?
- How is the new system better than the old?
- In what ways is the old system better?
- How did the system affect management/labor relations?
- Was there a fear of jobs being lost as a result of system deployment?
- Were jobs lost/created as a result of the system deployment?
- Did you participate in any training for the system?
- Do you think the training materials helped prepare you to use the system?
- Did any part of the system need better explanations in the training materials?

Identify Users' Ability to use ITS Data:

- Did the system provide data useful for decision making?
- Did the system provide data useful for other operations (such as tracking/ monitoring)?
- Do you think the system provided correct information?
- Did the system provide too much or too little information?
- Was the system difficult or easy to use? Why?

Survey Questions:

(*Scale is Strongly Disagree to Strongly Agree, Yes/No, Never to Always, Pick from List, Open-ended*)

Identify Perceived Benefits for the Users:

- Installing the seals in Tacoma (versus abroad) had a positive impact on system operations?
- The system was useful for logistics?
- The system was useful for management of transportation resources?
- The system provided timely information?
- Overall, you are satisfied with the system? Why?
- The system especially useful? How?
- What were the benefits to using the new system? (Pick from list)
- What were the drawbacks to using the new system? (Pick from list)

Identify User Acceptance of the ITS Systems

- Overall, you feel comfortable using all system features and capabilities?
- How often do you use the system? (Never to Always)
- Was the system helpful?
- What was your favorite feature? (Pick from list)
- What was your least favorite feature? (Pick from list) Why?
- The new system better than the old? How?
- The old system better than the new system?
- In what way(s) (Pick from list)
- The system affected management/labor relations? How?
- There was a fear of jobs being lost as a result of system deployment?
- Jobs were created as a result of the system deployment?
- Jobs were lost as a result of the system deployment?
- Did you participate in any training for the system? (Yes/No)
- Do you think the training materials helped prepare you to use the system? (Yes/No)
- Did any part of the system need better explanations in the training materials?

Identify Users' Ability to use ITS Data:

- The system provided data useful for decision-making?
- The system provided data useful for other operations? How?
- The system provided correct and accurate information?
- The system provides too much information?
- The system provides too little information?
- The system was easy to use? Why?
- The system was difficult to use? Why?