A Renewal Project Brief

SHRP 2 Tools for Underground Utility Location, Data Collection, and Analysis

MARCH 2012

The Common Ground Alliance estimates that there are 35 million miles of underground utilities in the United States. That's about the same as the distance between Earth and Mars. Every day, utilities made of less-detectable materials are installed deeper underground. Much of the existing data on utility location, composition, ownership, and status (that is, whether active or abandoned) is missing, incorrect, or incomplete. Current technologies and tools can only find 80–90% of existing utilities. Finding the other 10–20% and successfully managing utility conflicts require new tools.

When a highway construction project is surprised by a utility, the results can include redesign costs, delay costs, change orders, claims, and damages (including repairs, environmental releases, and even human casualties). To reduce these negative impacts, several SHRP 2 projects are developing new tools to help locate and characterize underground utilities, as well as new tools to identify utility conflicts and solutions.

This document provides an overview of the SHRP 2 projects related to underground utilities. It includes a brief description and the status of each project. SHRP 2 hosted webinars on these projects in February 2012 and August 2011. Recordings of these webinars and PDFs of the slides are available on the webinar section of the SHRP 2 website: www.TRB.org/SHRP2/webinars.

Encouraging Innovation in Locating and Characterizing Underground Utilities

Throughout the years, underground utilities have proliferated within highway rights-of-way. The location and nature of many such utility lines have not always been properly documented. Moreover, the presence of underground utilities within the highway right-of-way and the lack of pedigree information about some utility lines present unique challenges for highway renewal activities, which often require relocation of underground utilities to ensure public safety. The untimely discovery of an unknown underground utility needing relocation is one of the major causes of delay during highway renewal projects and, as such, one of the major contributors to traffic disruptions and budget overruns. Decision makers in both transportation agencies and utility companies need timely access to accurate utility location information in order to minimize the risk of disruption during highway renewal activities.

In SHRP 2 Project R01, Encouraging Innovation in Locating and Characterizing Underground Utilities, researchers conducted a review of existing and emerging locating and mapping technologies, evaluated the existing locating needs, and developed a research and development plan to address those needs. The final report provides a thorough review of locating practices, current and emerging technologies, and recommended improvements.

SHRP 2
STRATEGIC HIGHWAY RESEARCH PROGRAM
Accelerating solutions for highway safety, renewal, reliability, and capacity

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This project also developed the Selection Assistant for Utility Locating Technologies (SAULT), which is a web-based software tool that serves as decision support for identifying effective utility-locating methods for particular site and project environments. To deal with the complexity and multi-attribute nature of subsurface utility engineering and geophysical tools, the project team developed SAULT as an expert-based system. An expert-based system attempts to reproduce the performance of one or more human experts in a particular field. With SAULT, the user operates the expert system through an interactive dialogue that guides the user through a series of choices to solicit the needed input. At the end of the analysis, the user receives a summary report listing all the utility-locating methods deemed suitable for the project under consideration and any condition improvements that may facilitate the locating activities. Examples of technology in the software tool can be found in the box "Technologies in SAULT."

Status: This project is complete. SHRP 2 Report S2-R01-RW: *Encouraging Innovation in Locating and Characterizing Underground Utilities,* SHRP 2 Report S2-R01-RW-2: *Development of the Selection Assistant for Utility Locating Technologies*, and SAULT are available on the SHRP 2 website.

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Technologies to Support the Storage, Retrieval, and Utilization of 3-D Utility Location Data

Departments of transportation (DOTs) need accurate and up-to-date utility information during project development in order to consider the impact on utilities. Designers are usually provided with this information at the beginning of a project, but they do not have a mechanism to ensure it is kept up-to-date. There is currently no system in place to track utility changes during a project and notify designers of the changes, so DOTs need to completely remap utilities for every new project.

The research team in project R01-A is creating a system that provides a single, up-to-date repository for 3-D utility location data within a project boundary. It will leverage existing permitting and one-call processes to create a change notification system, develop supporting administrative procedures, and use existing DOT 2-D and 3-D CAD design software. The system could reduce redesign work resulting from utility changes unknown to the DOT designers, reduce project delays in the design and construction phases, and reduce excavation damage to utility lines. As part of this project, the research team will adopt and adapt a 3-D utility data model (proprietary model or industry standard), utilize a spatial document management system, leverage existing 3-D software tools, create administrative procedures, and incorporate supporting best practices.

The products of this research will include a 3-D utility data model, an implementation strategy, a proof-of-concept system, and a final report. The final report will include recommendations for further implementation, and technical and administrative best practices. DOTs, one-call centers, vendors, and service providers can use the process model and best practices to support further implementation.

The new tools can provide an automated means of understanding change within a project area and provide new 2-D and 3-D views of utility change without laborious research time. However, the tools will require additional training and understanding of the system nomenclature and work flow, and DOTs may have to adjust their work practices to use these tools. These tools can improve coordination, reduce risk of project redesign or delays, and reduce excavation damage. Over time, the tools could produce a current and comprehensive map of all utilities in a right-of-way, reducing or eliminating the need for new utility mapping at each project initiation.

Status: This project is active. A pilot project with Virginia DOT, Virginia Utility Protection Services, and participating utility companies will be conducted in mid 2012. The project will be complete in December 2012 and the final report will be available in 2013.

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Utility-Locating Technology with Multiple Sensors

Because utilities have differing materials, sizes, depths, conductivity, ground conditions, surface obstacles, and other characteristics, it is often necessary to use multiple sensing techniques to acquire an image of them. However, making multiple passes with different instruments is not as efficient as making one pass with a device that has multiple sensors. Combined with improved coupling techniques, a multi-sensor platform may lead to enhanced, perhaps automated, interpretation (better quality, lower risk) and better efficiency (less disruption and cost).

SHRP 2 Project R01-B, Utility-Locating Technology Development Utilizing Multi-Sensor Platforms, will support improvements in the detection and accurate determination of positions of buried utilities. The objective of this project is to develop digital geophysical mapping that can work in conjunction with common pipe and cable locating tools to offer more complete confirmation and verifica-

Technologies in SAULT

Array of Induction Receiver (AIR) System

This system is based on electromagnetic induction measurement techniques and operates on the same basic principles as traditional handheld radio-detection devices. An electric current is induced in a subsurface utility line. The induced current produces a magnetic field that is detected at the surface. The AIR system provides 48 simultaneous magnetic field measurements over an 8-ft. swath.

Radar MALA Easy Locator

The manufacturers claim that this device is capable of using high-frequency antenna for locating objects with diameters of 1 in. at a depth of 8 ft. and of locating objects with diameters 2 in. at a depth of 15 ft. using a mid-range frequency antenna. This GPR has a rough terrain cart for locating in rough areas.

Low-Frequency Conductive P/C Locator

The low-frequency conductive P/C locator has a built-in ohmmeter in the transmitter, which senses and measures the presence of external voltage while the receiver shows the received signal and its closeness to the cable. The lightweight earth contact frame directs the operator towards a fault.

Multichannel GPR: RFIL (Time-Step Frequency GPR)

The use of very short pulses (~1 nanosecond) and a repeated pattern of carefully timed and slightly offset signals support a high level of resolution (±50 mm), currently achievable only by high-frequency (1 GHz) GPR systems. Combining deep penetration and high resolution, the RFIL system can locate small targets such as inch-size plastic pipes at significant depths through challenging soils conditions.

Radio Mode: TW-8800

The TW-8800 uses three modes of active locating: conductive, inductive, and a coupling clamp. It also has two modes of passive locating: power (50 Hz/60 Hz) and radio (14 kHz and 30 kHz). The power mode can sense electrical lines and radio mode can sense redirected radio waves.

tion to *minimize*, not eliminate, the need for test holes. The more geophysical techniques used, the better the chance of performing a complete investigation beyond that of underground infrastructure that can include other targets of interest, such as pavement thickness, depth to bedrock or ground water, buried debris, and soil layers.

The systems being developed in this project include a high-frequency seismic imaging system, seismic modeling software, an improved time-domain electromagnetic induction (TDEMI) system, and improvements to data management software. The prototype seismic system will have a detection footprint and data format comparable to that of a multi-channel ground-penetrating radar unit, but use horizontal shear wave seismic reflection rather than radar reflection to image the subsurface. A portion of this project focuses on the development of modeling software to analyze the seismic measurements; in this task, real-world attenuation parameters, various sensor geometries, and target orientations are being introduced and simulated within the model. The TDEMI prototype system will be able to create a digital record (consisting of thousands of data points) of both detection samples and their associated precise position. The digital record can be used to conduct a detailed post-data-collection analysis performed by an experienced geophysical data processor in an office setting.

The software being developed will include the dynamic linking of maps, geophysical databases, and data profiles, as well as an automated depth slicing feature and arbitrary oriented cross-sectional view through a graphical/digital interface. These software advancements will facilitate a more streamlined and systematic workflow through the development of a more centralized analysis platform that will incorporate new improvements in data visualization, data management, and automated target selection routines.

These products are designed to advance the ability to rapidly and reliably locate and identify underground utility lines. Collecting data through multiple sensors reduces data acquisition time, lane closures, and training requirements. Having more reliable information reduces the likelihood of project delays from utility conflicts.

Status: This project is active. The report will be available online in mid 2013. Field testing of the TDEMI system will be conducted this year; it could be commercially available by 2013. A proof-of-concept seismic prototype can be built by 2013, and a refined production prototype could be available by 2015.

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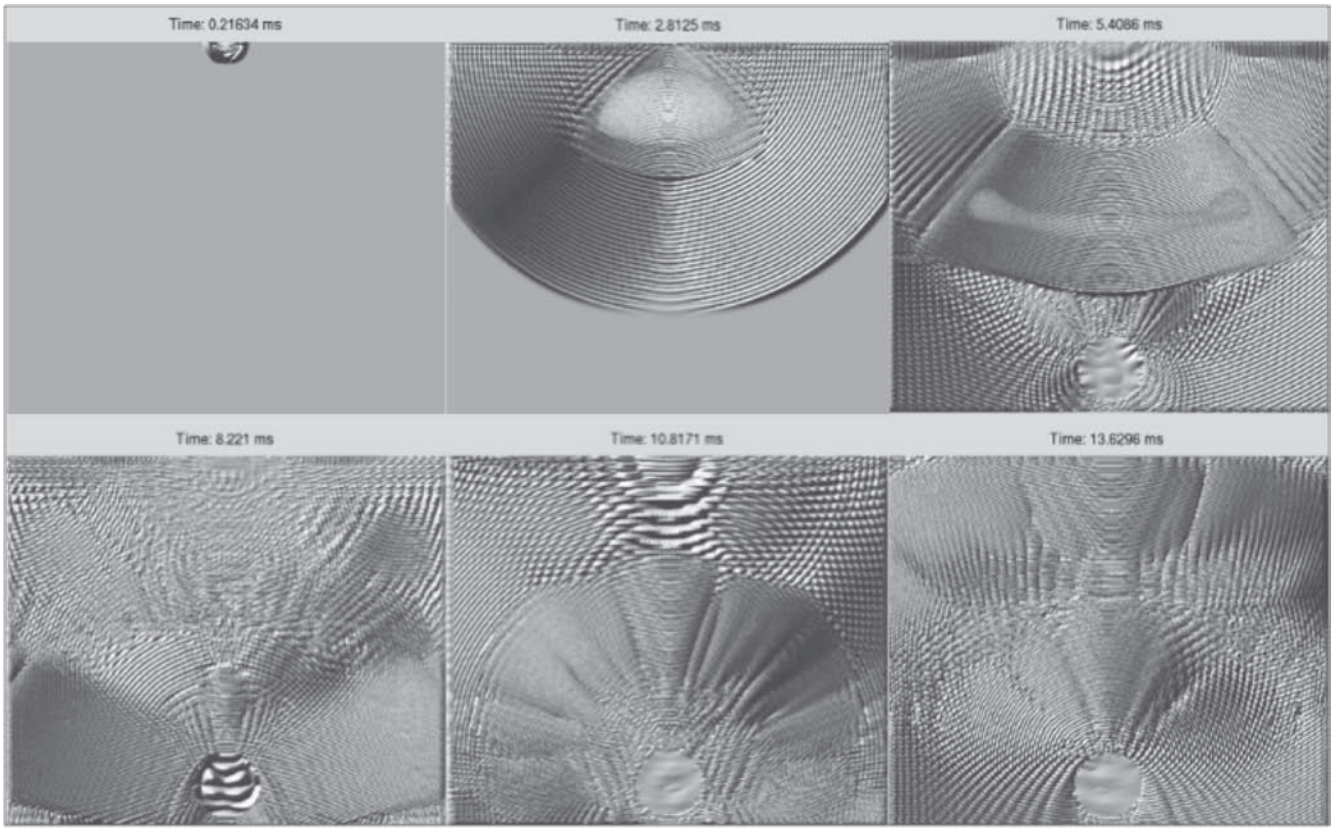

This image shows screen captures from left to right of a modeled seismic wave propagation path traveling from the ground surface (upper left) downward toward a cylindrical object (first seen in upper right) and then reflecting from the cylindrical object.

Innovations to Expand the Locatable Zone for Underground Utilities

Modern installation processes for installing underground utilities frequently require the utility company to go deeper. When utilities are installed deep, it can lead to "stacked" infrastructure. In addition, the materials that comprise modern utilities are more difficult to detect than traditional materials. To adapt, we need to improve both our means of locating deep infrastructure and our means of maintaining location data.

The objective of SHRP 2 Project R01-C, Innovations to Expand the Locatable Zone for Underground Utilities, is to improve the detection and accurate determination of the positions of buried utilities within an expanded locatable zone up to Quality Level B as defined by the American Society of Civil Engineers (ASCE) Standard Guideline for the Collection and Depiction of Existing Subsurface Utility Data (CI/ASCE 38-02), using any appropriate methods without duplicating the scope of project R01-B. This project is testing prototype technologies for locating buried facilities that are of diverse composition, at depths of up to 20 feet, obstructed or "stacked," and in the challenging road construction environment.

The tools being tested include a seismic reflection locator, an active/passive acoustic locator, long-range radio-frequency identification (RFID) tags, and a scanning electromagnetic (EM) locator. The seismic system targets all pipe materials, is staged completely above ground, uses shear waves to resolve smaller targets, and works in clay soils where ground-penetrating radar does not. Its current seismic techniques are suited for large and deep targets. The acoustic locator can target any pipe material and improves discrimination among facilities. The RFID tags have a range of up to 40 feet with a hand-held reader, a battery life of 20+ years, and IEEE 1902.1 public protocol communication. The EM locator uses low-frequency EM for depth of penetration; however, unresolved signal-strength issues are delaying testing and it may be dropped from the testing program. The technologies advanced in this project expand the 'locatable' zone of deep utilities with improved reliability. This location data eliminates delays when transportation projects involve underground utilities. The products of this project will include a user guide and training materials.

Visible Asset Inc.'s long-range RFID tag

Status: This project is active. The report, user guide, and training materials will be available online in early 2013.

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Integrating the Priorities of Transportation Agencies and Utility Companies

Issues related to utilities are among the major causes of construction delays in highway construction projects. Because of the frequency with which utilities occupy existing highway rights-of-way, highway renewal projects are prone to setbacks related to relocation of existing utilities. Lack of accurate information on the location of underground or overhead utility assets, inadequate estimation of the time and budget needed to conduct utility relocation activities, and insufficient coordination and cooperation between transportation agencies and utility companies are among the key factors that contribute to construction delays. The demand for accelerated project delivery while minimizing the impact to the traveling public further highlights the need for adequate coordination and cooperation between highway agencies and utilities for many highway renewal projects.

Under SHRP 2 Project R15, Strategies for Integrating Utility and Transportation Agency Priorities in Highway Renewal Projects, a research team investigated how to improve coordination between utility companies and transportation agencies to reduce the negative impacts to both and to the public. The research was divided into two distinct, although not explicit, phases. The first phase of the project focused on data gathering to identify existing institutional issues and processes that contribute to delays in planning, designing, and constructing highway renewal projects, as well as identifying proven innovative practices, policies, and procedures to mitigate these delays. The second phase of the project focused on data analysis and development of recommendations. The team's findings and developed strategies for improving coordination between public agencies and utility companies were shared with an internal advisory panel in order to refine the recommended best practices and strategies. Based on the results, the research team developed a tool box of best practices and a set of recommendations for future research projects that could relieve the institutional barriers for effective utility relocation activities.

SHRP 2 Report S2-R15-RW: *Integrating the Priorities of Transportation Agencies and Utility Companies* documents

current practices, opportunities for improvement, and anticipated barriers for integrating utility and transportation agency priorities in highway renewal projects. Thirteen best practices that span the whole project life cycle are also documented in a tool box format. Finally, the report provides a plan for future research in this field.

Status: This project is complete. Report S2-R15-RW is available on the SHRP 2 website.

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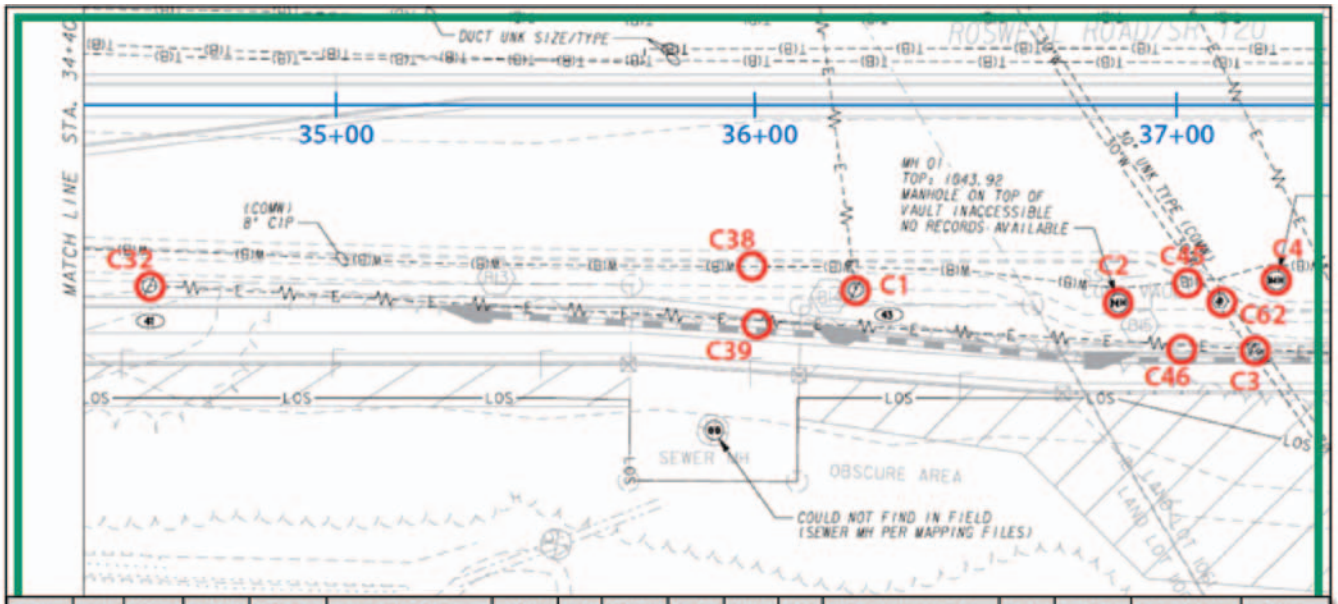
Identification of Utility Conflicts and Solutions

Two critical factors that contribute to inefficiencies in the highway project development process are (a) the lack of accurate, complete information about utility facilities that might be in conflict with the project and (b) the resolution and overall management of those conflicts. When utility relocation is involved, construction generally takes longer and costs more. Identifying and resolving potential utility conflicts early in the design process can minimize these delays and costs. Utility conflict matrices enable users to organize, track, and manage these conflicts.

The report for SHRP 2 Renewal Project R15-B, Identification of Utility Conflicts and Solutions, provides comprehensive, optimized concepts and procedures for identifying and resolving utility conflicts that public agency and utility professionals can use to improve the highway project development process. The tools developed include utility conflict matrices (UCMs) that enable users to organize, track, and manage the conflicts that frequently arise when utility lines are under highways.

Procedures involving the use of UCMs vary widely across the country. This project began with the documentation of these procedures and then developed optimized UCM concepts and techniques. The major research activities were the review of current practice; the development and testing of an optimized UCM concept; the development of a one-day training course to instruct end users on how to use the optimized concept and tools; and pilot tests of the training for two state DOTs to fine-tune the course. In addition, implementation strategies and guidelines were developed that include specific steps to start and continue implementation. The optimized UCM techniques include a prototype standalone UCM in Microsoft Excel format that includes a main utility conflict table and a supporting worksheet to analyze utility conflict resolution strategies. Project



Utility Owner	ID	Sheet No.	Utility Type	Size/ Material	Utility Conflict Description	Start Sta.	End Sta.	Start Offset	End Offset	Inv. Need	Test Hole	Recommended Action	Rsp. Party	Est. Res. Date	Res. Status	Cost Analysis
	C3	1	WM	30"	Proposed 18" drainage pipe would cross WM.	37+20		60' Rt		QLA	3	Review possibility of adjusting drainage pipes up to avoid conflict, lowest structure (B13) is at 5.6'.	D	n/a	Utility conflict identified.	

Solution sheet from the UCM training course

products also include a prototype utility conflict data model and database. This standalone product is a scalable UCM that enables the management of conflicts in a database environment.

The one-day UCM training course developed in this project includes the following features:

- A lesson plan (six lessons—three in the morning and three in the afternoon);
- Presentation materials in PowerPoint format;
- Presenter notes;
- Participant handouts, including presentation handouts, sample project plans, and UCM templates; and
- A companion CD, which includes all the training materials and a copy of the prototype utility conflict database.

A critical component of the UCM training course is the hands-on utility conflict analysis in which participants analyze a set of plan sheets and other documentation to identify the location of utility conflicts and use a UCM to document and manage each conflict. At the end of the hands-on exercise, participants are given a copy of a solution sheet that shows the location of all utility conflicts and sample UCM records.

New efficiencies can result from having more standard procedures for documenting and managing utility conflicts. These products help optimize utility-related activities and simplify coordination between transportation agencies and utility companies, which will reduce a major cause of delay in highway construction projects.

Status: This project is complete. The final report, UCMs, and training course will be available in mid-2012.

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SHRP 2 Utility Projects

PROJECT NO.	PROJECT TITLE
R01	Encouraging Innovation in Locating and Characterizing Underground Utilities
R01-A	Technologies to Support Storage, Retrieval, and Utilization of 3-D Utility Location Data
R01-B	Utility-Locating Technology Development Utilizing Multi-Sensor Platforms
R01-C	Innovations To Expand the Locatable Zone for Underground Utilities
R15	Strategies for Integrating Utility and Transportation Agency Priorities in Highway Renewal Projects
R15-B	Identification of Utility Conflicts and Solutions

SHRP 2 Renewal Reports Now Available

IN PRINT FROM TRB BOOKSTORE, AS E-BOOKS, AND ONLINE

Strategies for Improving the Project Agreement Process between Highway Agencies and Railroads (SHRP 2 Report S2-R16-RR-1)
E-Book for iPad, Kindle, Google Bookstore

IN PRINT FROM TRB BOOKSTORE AND ONLINE

Guidelines for the Preservation of High-Traffic-Volume Roadways (SHRP 2 Report S2-R26-RR-2)

Encouraging Innovation in Locating and Characterizing Underground Utilities (SHRP 2 Report S2-R01-RW)

Integrating the Priorities of Transportation Agencies and Utility Companies (SHRP 2 Report S2-R15-RW)

ONLINE ONLY

Preservation Approaches for High-Traffic-Volume Roadways (SHRP 2 Report S2-R26-RR-1)

Project Brief: Preservation Approaches for High-Traffic-Volume Roadways

A Plan for Developing High-Speed, Nondestructive Testing Procedures for Both Design Evaluation and Construction Inspection (SHRP 2 Report S2-R06-RW)

Project Brief: Tomorrow's Bridges

Project Brief: Railroad-DOT Institutional Mitigation Strategies

Project Brief: DOT-Utility Coordination: Understanding Key Aspects of the Problem and Opportunities for Improvement

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