Development of the Joint Weigh-In-Motion (WIM) and Measurement Reach Back Capability (WIM-RBC) – The Configuration and Data Management Tool for Validation, Verification, Testing and Certification Activities

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Abstract

The development of the Joint Weigh-In-Motion (WIM) and Measurement Reach Back Capability (WIM-RBC) embodied in the current WIM Gen II system demonstrates a configuration and data management strategy that ensures data integrity, coherence and cost effectiveness during the WIM and Measurement systems validation, verification, testing and certification activities. Using integrated Commercial-off-the-shelf (COTS) products, the WIM-RBC is based on a Web services architecture implemented through the best practices of software design with the Unified Modeling Language (UML) and eXtensible Markup Language (XML) schema. Fielded WIM and measurement systems and XML-compliant messages can engage the WIM-RBC to store collected data in the WIM-RBC information repository. Through a Web browser, authorized users can securely access this repository, generate reports, and obtain separate tabular data for follow-on, custom analysis. It is the intent of the WIM-RBC to store all collected measurement data that will ultimately be used to determine the life-cycle cost of the WIM and measurement systems.

The Logistics Transformation Agency (LTA) serves as the Army G-4 principal agent for Science and Technology matters. In that capacity, LTA has a permanent seat on the Army Science and Technology (S&T) Working Group and is an advocate for change in Logistics Transformation in the field of S&T. LTA is also the Army Deputy Chief of Staff, Logistics (DCS, G-4) representative on a number of technology and transformation boards, panels and integrated process teams. Science and Technology is fundamentally joined with Army Transformation goals. S&T must be comprehensive in providing solutions to enhance our efforts in fielding capabilities to achieve joint, network-centric, distributed forces capable of rapid decision superiority and massed effects across the battlespace. This past year the Army G-4 delineated four focus areas in logistics that S&T will be critical in providing solutions to logistics capability gaps. LTA has investigated leading edge technologies for potential logistics applications. These technologies have the promise to drastically change how we perform logistics functions and permit military operations with demand for fewer logistical services. LTA has also analyzed on-going S&T work for its implications to logistics doctrine, policy and force structure. Emphasis was placed on identifying those things that either have the potential to make logistics processes more efficient or negatively impact upon logistics operations.

The Oak Ridge National Laboratory (ORNL) has been involved in Weigh-in-Motion (WIM) Research with both government agencies and private companies since 1989. The discussion here will focus on the United States Army's need for an automated system to weigh and determine the center-of-balance for military wheeled vehicles as it relates to deployments for both military and humanitarian activities.

Keywords: Weigh-in-Motion, WIM, Reach Back Capability, Center-of-balance, Defense Deployments, Aircraft Load Planning, Validation, Verification, Testing, Certification, Web Services, UML, XML, XML Schema, Database, Information Repository

Introduction and Background

The United States Department of Defense must maintain the capability to rapidly project massive combat power anywhere in the world with minimum preparation time. Currently, personnel use portable individual wheel weight or fixed in-ground static scales, tape measures and calculators to determine vehicle axle weights, total vehicle weight and center-of-balance for vehicles and palletized cargo to be shipped via railcar, sealift, or airlift in support of military and humanitarian operations. The process of manually weighing and measuring all vehicles and cargo subject to these transshipment operations is time-consuming, labor-intensive, and most importantly is prone to human errors that can result in safety hazards and inaccurate data.

Errors can result from inaccurate or incomplete identification of vehicles and equipment; misreading a scale or tape measure, manually recording data incorrectly; manually miscalculating the axle weight, total vehicle weight or center-of-balance; and transferring data from manually prepared work sheets into an electronic database via keyboard entry personnel. Many of these errors can greatly increase during stressful deployment times and adverse weather conditions.

Errors in determining weighs and balances in military deployments as well as commercial air transport can be fatal. In June 2002, a special operations combat supply plane crashed in Afghanistan, killing several of the crew. U.S. Air Force accident investigators concluded that the crash was caused by "imprecise information" about cargo weight combined with a "get the job done" attitude. The aircraft crashed not because it was overloaded but because it was overweight for the location, 7,200 feet above sea level. *Army Times* reported that weighing cargo at such isolated airstrips was not practicable —the Air Force special operations crews were relying instead on weight estimates (Rolfsen, 2002).

A Weigh-in-Motion (WIM) system may also have applicability in response to the National Transportation Safety Board's February 2004 recommendation that federal regulators and the airlines develop methods to weigh passengers and baggage to prevent overloading of airplanes (Levin, 2004). The safety board had concluded that the crash of Air Midwest Flight 5481 on January 8, 2003, was caused by too much weight in the rear of the aircraft combined with a maintenance mistake. The United States military has recognized and documented a need for WIM technology (Keane, 1996) and further documented the requirement (Coats, et al., 2004a) and a recommended WIM technology solution for military applications in 2004 (Coats, et al., 2004b).

In this paper, we will concentrate on the configuration and data management aspects of military applications of WIM. We will discuss specific aspects of the United States Army/Oak Ridge National Laboratory WIM program which will include the discussions of: 1) the configuration control of both the configuration of the WIM device and its software, and 2) the data management of all weighing and measurement data collected from the ORNL WIM Gen II pre-production system, 3) the architectural components of the WIM-RBC Configuration and Management Tool itself, and 4) aspects of processing with respect to configuration and data management.

The lack of a standardized airlift-weighing system for joint service use also creates redundant weighing requirements at the cost of scarce resources and time. The process of determining the vehicle weight, center-of-balance, and individual axle weights for load planning and assets visibility consists of: staging and identifying the vehicle; determining the individual wheel weights; determining the axle spacing; calculating the total weight, center-of-balance and individual axle weights; marking the vehicle with its total weight and center-of-balance; accumulating the vehicle data for a group of vehicles; and finally entering the data into an electronic database to enhance military planning and visibility capabilities. Presently, the entire process is performed manually using a large static truck scale or multiple individual portable wheel weight scales, tape measures, calculators, and clipboards. The process is very time consuming, manpower intensive and prone to human errors. The WIM system, in Figure 1 can greatly reduce the time required performing this operation and eliminating the human errors resulting from the manual nature of these measurements, calculations, and data input.

Key Features of WIM-RBC

The objective of the WIM-RBC is to provide a secured, web-enabled, and central data and service repository for configuration and data management processing that is used to continuously analyze and improve the WIM system. The WIM-RBC stores and retrieves disparate types of system, logistics, and technical information in the form of text, data, images, and video using relational SQL-based data sources, flat files, and external Web Services as required. All of this is readily accessible through a simple Web browser User Interface (UI). The information storage and access is executed immediately over the Internet.

Figure 2 provides a high-level system design of the WIM-RBC. WIM fielded and test equipment push information to the WIM-RBC over the Internet using eXtensible Markup Language (XML) that includes the schema (format) and contents for: (1) the Deployment Equipment List (DEL), (2) detailed WIM scale data, (3) images (such as jpegs) of vehicles, (4) additional conveyance information, (5) measurement and timing data, (6) weather data, and (7) video as required. The XML is validated, processed, and committed to the database through the WIM-RBC Web Services interface. The detailed WIM scale data includes the "raw" data from each pad for each weight measurement. This data is used for further analysis to identify efficiencies, improvements, and performance correlations. By design, all information concerning WIM operations and equipment, including equipment manufacturer, serial number, model, and specifications are stored in the WIM-RBC data repository.

In addition to storing configuration, operational, and test information, the WIM-RBC also hosts the configuration control for the WIM software using Subversion, the Next-Generation Open Source Version Control source code version control from the CollabNet Open Source community (CollabNet, 2005). The versioned WIM software includes the source code for the WIM scale micro-processor and WIM Host microprocessor (Windows XP operating system), Handheld Controller (Windows Pocket PC (PPC) operating system) user software, the Local WIM Relay Host, and the WIM-RBC software.

For the user, WIM-RBC provides a secured, Web browser user interface (UI) that is used to access and manage the services and data repositories from anywhere on the Internet. The UI was designed to be simple to allow authorized users to submit information, query, edit/update, produce reports, and produce tabular formed data for follow-on analysis and processing.

WIM-RBC Data and Processing

The WIM-RBC information is modeled using two complementary forms: the

Unified Modeling Language (UML) and the WIM-RBC XML Schema. UML is the standard object-oriented notation that facilitates modeling the structure, architecture, and behavior of systems, software, and data. An XML Schema describes the structure or format for an XML document for such things including the contained elements, the order of the elements it contains, and the quantity and relationship of each element.

Figure 3 illustrates an overview of the WIM-RBC UML structural or class diagram. Note that the attributes and cardinality have been filtered in this view for clarity. The UML class diagram is divided into 4 main sections: (1) DEL Model, (2) WIM Scale Details, (3) Vehicle Details, and (4) Vehicle Tracking.

The DEL model is used to store all the elements for Military items that are planned for movement and measured by the WIM System for load planning. In addition to this relational model primarily used for query and reporting, the DEL in its raw text-based format (for example as processed by TC-AIMS II) is stored in the file system. The WIM Scale details model provides the storage and access for the data collected during a weight and measurement session for a particular vehicle. Although the DELTransport class identifies vehicles, a separate Vehicle class is provided in the Vehicle Details model for those vehicles that are measured during a non-Military or non-DEL exercise and testing. Such activities are part of the on-going verification process for the WIM system involving laboratory evaluations and commerce operations. Finally, the Vehicle Tracking model is a Route design pattern that is used to record the movement of a vehicle with respect to the WIM Systems that may be used in its transport path. This is particularly useful in commerce and inter-modal multi-leg transports where a vehicle crosses one or more states in CONUS or country jurisdictions.

All measurements for vehicle including but not limited to weights, detailed weights, cube data, and images are stored in the WIM-RBC repository. In figure 3, each Vehicle can have many measurement packages (called MeasurementPacks) such that Vehicle measurements can be stored if it is measured many times during a single loading session.

For the WIM-RBC, the XML Schema directly reflects the UML model including not only the attributes of each class but also the relationships among the classes. Figure 4 provides an example of the schema that describes part of the UML in Figure 3.

The UML is used to drive the storage repository design. To complement this, the XML schema is used to drive the message format design for communications to the WIM-RBC and among the WIM software components. This schema serves as the foundation for a common communications protocol and any authorized fielded or test system that posts data conforming to the XML standard. In this way, posts are saved to and made available to the WIM-RBC service.

Summary

The development of the Joint Weigh-In-Motion (WIM) and Measurement Reach Back Capability (WIM-RBC) embodied in the current WIM Gen II system demonstrated a configuration and data management strategy that ensures data integrity, coherence and cost effectiveness during the WIM and Measurement systems validation, verification, testing and certification activities. The WIM-RBC is based on a Web services architecture implemented using COTS products, through the best practices of software design with the Unified Modeling Language (UML) and eXtensible Markup

Language (XML) schema. Fielded WIM measurement systems and XML-compliant messages are engaging the WIM-RBC to store collected data in the WIM-RBC information repository. Through a Web browser, authorized users securely access this repository, generate reports, and obtain separate tabular data for follow-on custom analyses. The WIM-RBC intends to store all collected measurement data that will ultimately be used to determine the life-cycle cost of the WIM measurement systems (including related measurement systems such as volumetric and center of balance).

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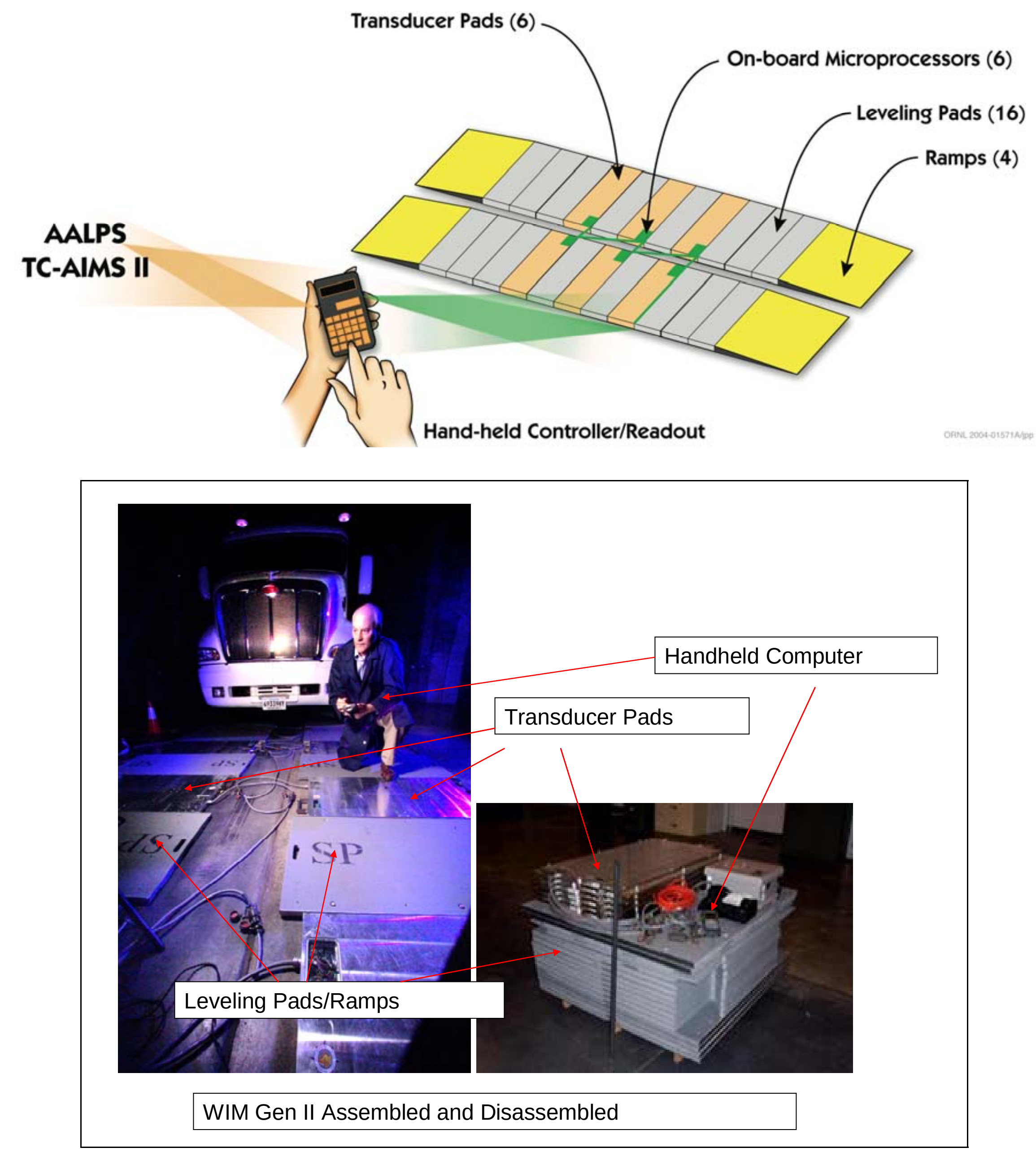

Figure 1 WIM Gent II Artist Conception (above) and Actual WIM Gen II Assembled/Disassembled (below).

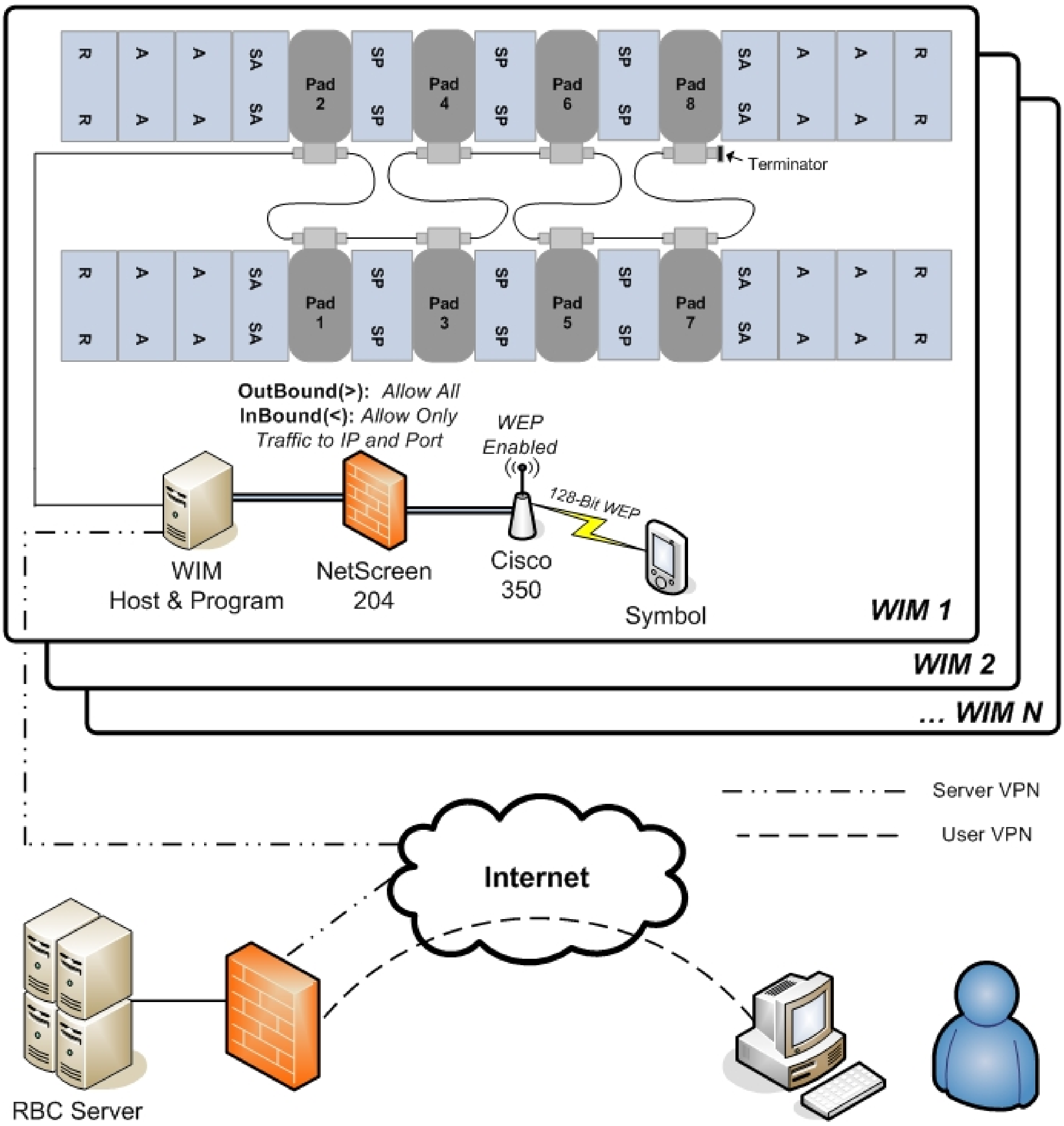

Figure 2. WIM/RBC High-Level System Design.

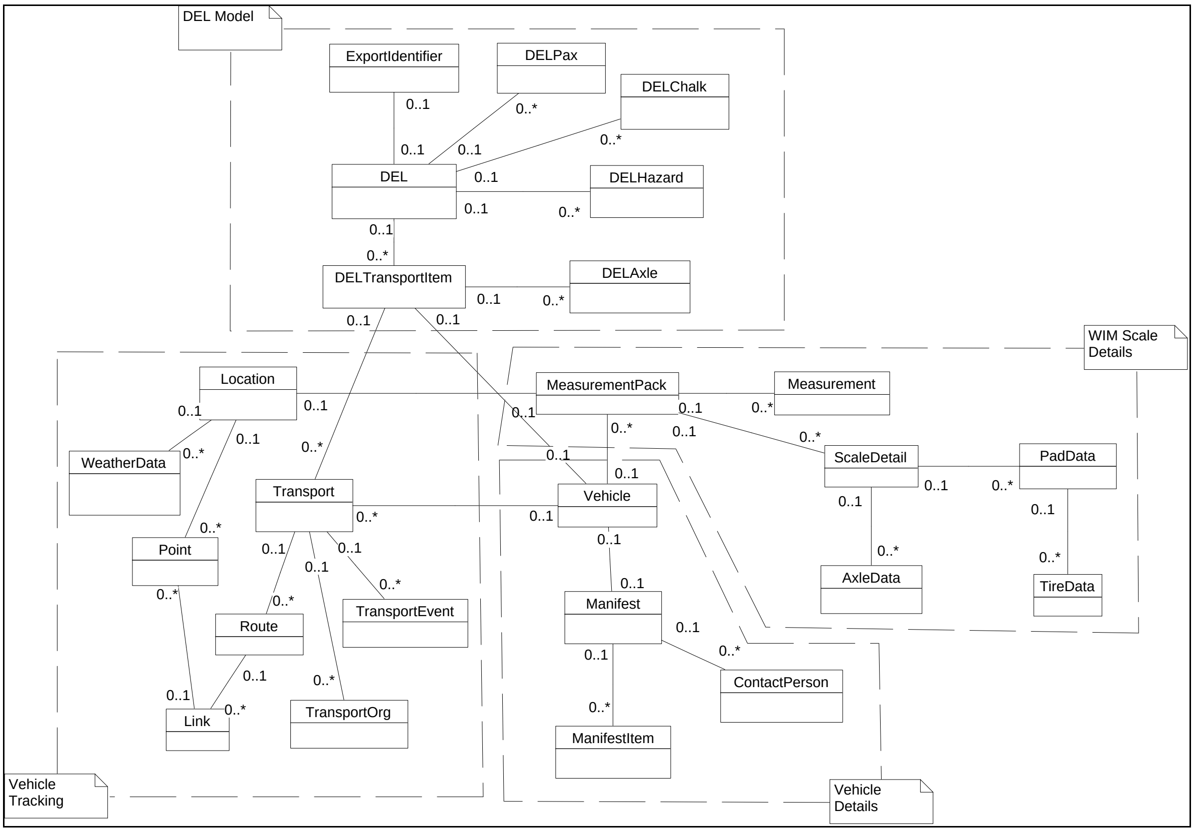

Figure 3. WIM-RBC UML Class Diagram Overview

```
<xsd:schema xmlns:xsd="http://www.w3.org/2001/XMLSchema">
<xsd:element name="DEL" type="DELType"/>
<xsd:complexType name="DELType">
<xsd:sequence>
<xsd:element name="RecordType" type=" xsd:string "/>
<xsd:element name="PlanId" type="xsd:integer"/>
<xsd:element name="PlanLegId" type="xsd:integer"/>
<xsd:element name="PlanName" type="xsd:string"/>
<xsd:element name="POECode" type="xsd:string"/>
….
</xsd:sequence>
</xsd:complexType>
…
</xsd:schema>
```

Figure 4. A portion of the WIM-RBC XML Schema