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TR NEWS

Moving Today's Military

- Commercial Carrier Partnerships
- Fast Ferry Experiments
- Portable Weigh-Ins

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People, Sessions, Activities: 2004 Annual Meeting

WEIGH-IN-MOTION TECHNOLOGY for Military Operations

Developing a Portable, Safe, and Accurate System

JULIUS E. COATS, JR., ROBERT K. ABERCROMBIE, DAVID L. BESHEARS, AND ROBERT B. HONEA

Coats is National Laboratory Liaison, Department of Energy, to the U.S. Army Training and Doctrine Command, Fort Monroe, Virginia. Abercrombie is Senior Program Manager, Computational Sciences and Engineering Division, Oak Ridge National Laboratory (ORNL), Oak Ridge, Tennessee. Beshears is Senior Researcher, Engineering Science and Technology Division, ORNL. Honea is Technology Consultant, ORNL.

Weighing vehicles and other cargo before loading them onto aircraft in a theater of operations is critical to the deployment of U.S. military forces. Rolling stock and other cargo must be weighed and measured accurately to calculate the center of balance of each item for proper distribution of weight in the aircraft. The weighing and measuring are vital to the safety of the aircraft, the crew, and any passengers. Errors can be fatal.

In-ground static scales for weighing are available at most air bases in the United States, but not in remote or undeveloped areas. In June 2002, a special operations combat supply plane crashed in Afghanistan, killing several crew members. 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 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 practical—the Air Force special operations crews were relying instead on weight estimates (*1*).

Nevertheless, military procedure requires all equipment to be weighed before loading, without guesswork or estimates. The unit in Afghanistan had estimated a weight that was wrong by several thousand pounds. Each location requires specifically recalculating the cargo's weight and center of balance and taking into account the effects of altitude, temperature, runway length, and aircraft type.

U.S. military forces today are deployed globally and rapidly, often in areas with little infrastructure, rarely including an in-ground static weigh scale. New technologies are addressing this problem.

Tools in Hand

If an in-ground fixed weigh scale is not available for wheeled vehicles, individual wheel-weigh manual portable scales and tape measures are used to weigh military equipment and to determine the center of balance. Individual wheel-weigh scales are placed under each wheel, and all wheels must be on the scales at the same time, to ensure accuracy.

Demonstration of weigh-in-motion (WIM) at Fort Bragg, North Carolina, May 2003, with truck moving over portable system.

After weighing the individual wheels or wheel sets, the next step is to measure the distance between the axles and calculate the center of balance, the individual axle weights, and the total vehicle weight. The Air Force loadmaster uses the center-of-balance data and total vehicle weight to plan a specific load for each aircraft.

The process is time-consuming, exhausting, and prone to error, especially in adverse weather. Placing the individual wheel-weigh manual portable scales under the wheels of the vehicle also presents a safety hazard. The process requires 6 to 10 soldiers. The loadmaster uses the data to determine the safe loading of the aircraft. No Air Force pilot will take off without clearance from the loadmaster.

Improved Systems

Oak Ridge National Laboratory (ORNL), Oak Ridge, Tennessee, has been experimenting with and developing portable weigh-in-motion (WIM) systems for

more than 10 years. ORNL developed its first system for the verification program of the U.S.–Soviet missile disarmament agreement, to identify and verify the weights of missiles moved from production facilities, assembly plants, and deployment bases, or to destruction sites.

WIM systems have highway applications for commercial vehicles at low and high speeds. In the early 1990s, the Air Force Productivity, Reliability, Availability, and Maintainability Office commissioned ORNL to develop a portable WIM system for military deployment.

The military needed a tool that could weigh and determine the center of balance for wheeled vehicles and cargo, providing the data electronically for deployment, redeployment, and other inter- and intratheater activities. ORNL developed a system to register individual wheel weights, axle weights, axle spacing, total vehicle weight, and center of balance, regardless of the total number of axles.

The benefits of the WIM technology are many. The system offers portability, reduces labor, increases productivity, and eliminates human errors in transferring data and making calculations. In addition, portable WIM enhances deployability and reduces the logistics footprint with fewer items of equipment, so that the military can react quickly and effectively to any need.

The WIM system has commercial applications as well. State enforcement agencies could use portable units for random weight checks of commercial vehicles on highways and state roads where static weighing scales are not available. Additional industrial applications would include weighing trucks at facilities to assure proper weight distribution for safe travel.

The WIM system also may 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 (2). 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.

Inside the Technology

The portable WIM system weighs and records individual axle weights, measures and records the spacing between axles, and automatically determines the vehicle's total weight, individual wheel weights, individual axle weights, individual axle spacing, and longitudinal center of balance. The system improves the weighing process by reducing personnel hours and the time required for deployment and by eliminating opportunities for human errors from the manual transfer of data or from the miscalculation of vehicle attributes.

Weight data are measured as each wheel rolls over the system, which uses two to six transducer pads. By using the front wheels as a trip indicator and the last wheel to end the cycle, the system can collect and calculate the parameters automatically (see Figure 1).

All calculations are completed electronically in real time. The data can be relayed to the military's databases for deployment decision making, such as the Transportation Coordinators' Automated Information for Movement System II or the Automated Air Load Planning System.

Comparison Tests

Several side-by-side tests have been performed at Fort Bragg, North Carolina, and other bases to compare the portable WIM system with the weighing technologies now in use by the military—that is, with the in-ground static weigh scale used at home bases and with the individual wheel-weigh scale system used in

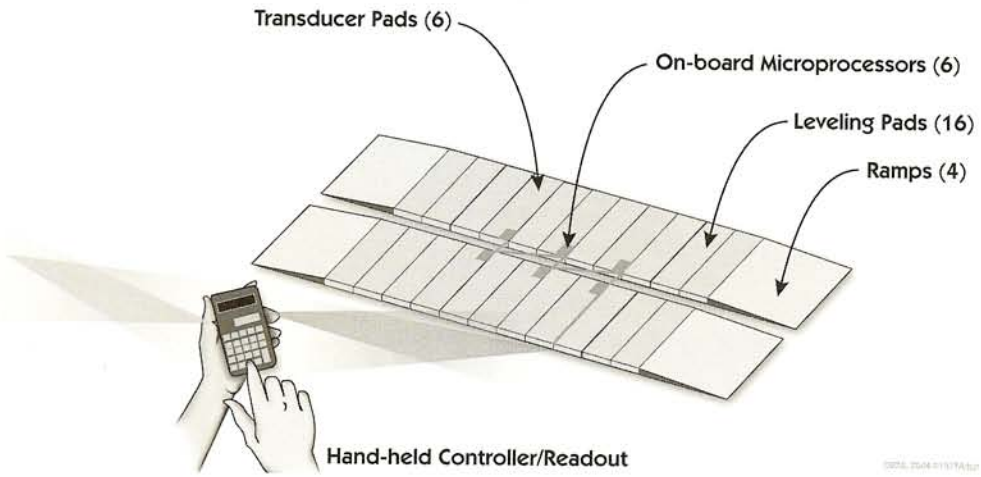

FIGURE 1 Typical new WIM system design.

TABLE 1 Average Times for Vehicle Preparation with Different Scales

Static scales with tape measure	Individual wheel-weigh scales with tape measure	Portable WIM system
7 minutes, 38 seconds	7 minutes, 46 seconds	3 minutes, 3 seconds

remote locations. The portable WIM demonstrated significant savings in time and labor and eliminated errors in manual entry and calculation.

A test compared the portable WIM with a commercial individual wheel-weigh scale system at Ft. Bragg in late 1996, weighing and determining the longitudinal center of balance of a 5-ton truck, a 2.5-ton truck, a 1-ton truck, and a tractor with a 40-foot trailer. The individual wheel-weigh scales weighed the vehicles and calculated the center of balance for the five vehicles in 25.3 minutes; the portable WIM system did the same in 4.4 minutes. Operating the portable WIM system required only three soldiers; the other method required at least eight soldiers to maintain speed in data processing.

A second set of tests in May 2003, again at Ft. Bragg, weighed and determined the center of balance of 23 vehicles and 1 container in a simulated deployment. The military vehicles included a high-mobility multipurpose wheeled vehicle, 5-ton wreckers, tractors with flatbed trailers, 5-ton vehicles with trailers, and a forklift.

The static weigh scale and tape measure technique required three operating personnel; the individual wheel-weigh scales and tape measure technique required seven; and the portable WIM system required three. The average times required to weigh, measure, determine the center of balance, and mark the individual vehicles are shown in Table 1.

The number of axles caused great variations in times for the static in-ground weigh scale and the single wheel-weigh scales. The portable WIM system consistently registered the same times, regardless of the number of axles.

Human errors in the calculations of vehicle attributes were 9 percent for the static weigh scale and tape measure technique; 14 percent for the individual wheel-weigh scales and tape measure technique; and zero for the portable WIM system. The tests were performed in excellent weather conditions, but in rain, snow, or high winds, the human error rate would be expected to increase for the first two techniques.

The main advantage of the portable WIM is the reduction of potential errors. The individual wheel-weigh scales and the static scales require the transfer of data from one device to another, as well as the manual calculation of individual axle weights, total vehicle weight, and center of balance. ORNL's portable WIM system will eliminate manual calculations and will feed the data directly into other systems for the automated management of deployment and load planning. The system also will free up military personnel to do other jobs.

Next Steps

ORNL is enhancing the portable WIM system with a new algorithm for accuracy of weighing, along with upgraded electronics, modifications for field use, interfaces to the databases for military deployment, and a capability to identify automatically the vehicle or cargo being weighed. State-of-the art load cell transducers and optimized spacing will maintain accuracy within 1 or 2 percent.

Although the system can be assembled and handled easily in the field by two soldiers, another focus is on trimming the weight for easier handling and assembly—perhaps with lightweight but strong composites. The objective is to develop a field-rugged system that can go anywhere the military deploys and that can weigh vehicles and cargo safely, provide the data automatically to all authorized systems and users, and be transported in the back of the last vehicle to be loaded.

In the Toolkit

WIM systems have been available in the commercial vehicle industry and enforcement services for more than a decade, with wider applications in Europe. If the portable version had been available to soldiers sooner, the fatal accident in Afghanistan might not have occurred.

The new portable WIM system will eliminate human errors in data entry and in calculations, increase speed and productivity in deployments, eliminate the need for a static weigh scale, support rapid force movement, and reduce costs. The system can go anywhere via aircraft and can be set up and operating in a few minutes. With portable WIM in the toolkit, soldiers will perform missions more efficiently, more accurately, and in greater safety.

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