Advanced Surveying Technology Reaches New Height in Track and Field

By John Stenmark, RLS and Hugh Baertlein

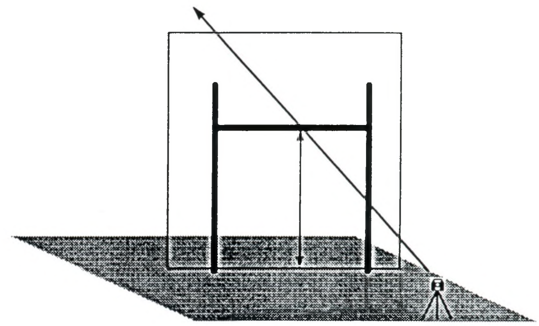
Our thanks to Don Edgar and Leica Canada for making this article avaliable to us.

Since its introduction to track and field in 1972, modern surveying equipment has been used for measurements at high level track and field competitions. As a subcontractor to swatchTIMING®, official timekeeper and partner of the 1996 Olympic Games, Leica provided distance measurement for the track and field events of the Centennial Summer Games. Swatch knows timing, but Leica knows distance measurement. Total stations are faster, more accurate and less obtrusive than tapes. Using custom software Leica's measurement team sent results directly to the networked electronic scoring systems. The resulting time savings set a fast pace for competition and eliminated data transcription errors. The measured events were the jumps (long and triple), pole vault, the throws (hammer, discuss and javelin) and the shot put. Four track meets were included in the contract with swatchTIMING®: the Atlanta Grand Prix, the US Olympic Trials, the Centennial Olympic Games and the Paralympics.

Members of Leica's Track and Field Measurement Team witnessed the world's elite athletes give 110% to be the best. The measurement team members had it much easier than the athletes -- the most difficult part of the survey task was staying focused on one specific event. At any given moment dozens of the world's best athletes were engaged in the highest level of competition all around us. To truly experience the spirit of the games, there was no better (not to mention more humbling) location than on the Olympic stadium field surrounded by world class athletes.

PRINCIPLES

A Leica TCA1100 total station with Automatic Target Recognition was the core of the track and field measurement system. Engineered for efficiency and productivity in the field, the TCA1100 was ideally suited for the steamy summer games. The total station measured horizontal and vertical angles and slope distance from the central axis of the instrument to a special reflector marking the impact point. The information was used to compute the reflector's 3-D position. The measured points were analyzed using standard coordinate geometry routines, from which cogo functions calculated the athletes performance. Once the judge targeted the measurement point, the entire measurement process, including data transfer, required approximately 10 seconds. Because of the variety of events measured three different techniques were used:



1. Long Jump, Triple Jump

To orient the total station, one point at each end of the takeoff board was measured. The two points defined the origin for jump measurement. After a legal jump, a judge placed a specially designedreflector at the landing point closest to the takeoff board. The total station measured the point and computed the perpendicular distance from the takeoff board origin to the landing point. If desired, a judge could mark and measure more than one landing point and select the shortest jump as the athletes official distance.

2.Throwing Events -- Hammer, Shot Put, Javelin, Discus

Before the event, the operator selected the throwing event option from the onboard software. A measurement to the throw ring center point was taken and recorded as the origin for all measurements. Check measurements were made to verify the correct radius of the ring. If the ring radius was in error, the system used multiple readings on the radius to determine the circle center. After each throw, an official placed the reflector at the implement's impact point. The "spotters," officials in the field who mark the impact point, remarked on the difficult of marking some discuss throws when the discuss struck the ground at a shallow angle and left only a small trail of flattened grass. Fortunately, the hammer was easier to spot. The 7.2 kg steel ball leaves a crater when it lands, often completely burying itself in the turf. The spotters said that even Ray Charles could spot the hammer! Once measured, the target was recorded and the horizontal distance between the center point and impact point was calculated. The throwing ring radius was automatically subtracted from the horizontal distance before the results were transmitted to the judge.

3. The Pole Vault

In track and field, pole vault required special attention. It was impractical to place a reflector on the crossbar, making direct measurement impossible. In conventional surveying, the elevation of inaccessible objects is often computed using the remote height principle. The computation assumes that an initial survey point is directly below the object. During the pole vault competition, the standards that supported the cross bar (over which the athletes literally launched themselves) were moved a few decimeters forward or back from the takeoff box, and it was impractical to re-measure the initial point during competition. The movable vertical plane defined by the standards and crossbar created difficulties for the conventional remote height principle. Therefore, a special technique was developed to ensure accurate height measurements for the pole vault.

The mathematical model of a ray intersecting a plane was used to compute the height of the crossbar. The computations are based on the measured relationship between the instrument, the horizontal plane at height zero and the vertical plane containing the crossbar. The ray -- plane intersection point is calculated from the vertical angle of the instrument when sighted to the lowest point on the top of the crossbar. The technique is explained in more detail later in the article.

EQUIPMENT

A Leica TCA1100 Total Station was used for all observations. The instrument utilizes a revolutionary co-axial automatic target recognition system (ATR) that automatically searched for and measured the target with greater speed and accuracy than a skilled operator. The instrument provided 3" angular accuracy and distance accuracy of 2mm + 2ppm, easily meeting the IAAF requirements. A circular retroreflector prism was used as the target for throwing events and high accuracy reflective tape targets were placed on the standards supporting the pole vault crossbar.

For the summer games, Leica developed special application software to run onboard the total station. The TCA1100 uses Leica's GeoBASIC, an enhanced BASIC command set providing simple commands for total station operation, data access, communication and MMI control The GeoBASIC system includes a language compiler and instrument emulator that accelerated alpha test and debugging of the track and field software. Due to the different configurations and requirements in the various events, separate programs were developed for throwing, distance jumping and height jumping. To simplify operation and allow "cross training" the onboard software was designed to provide a common interface between events. The instruments performed all computations and transmitted the results to the judge's computer via RS232 interface. As an added data backup, an event log file was stored on a removable 2MB PCMCIA memory card residing in the TCA1100.

Leica Jump Distance V 2.10					
Instrument	: TCA1100, Serial 415659, Chuck Lee				
User Templ.	: OLYMPICS				
Meas. File	: FILE)1.GSI				
Program Start	: 27/07/1996 at 19:04				
Station	: 1				
	E=	4.583m N=	-5.198m H=	0.000m hi=	0.000m
Reference Pt.	1				
Measure made	: 27/07/1996 at 19:05				
330	E=	0.000m N=	0.000m H=	-1.720m hr=	0.150m
Reference Pt.	2				
Measure made	: 27/07/1996 at 19:05				
331	: E=	0.000m N=	1.221m H=	-1.740m hr=	0.150m
Jump Distance Recorded					
Measure made	: 27/07/1996 at 20:03				
23	: D=	6.390m			
	: E=	6.392m N=	0.105m H=	-1.638m hr=	0.150m

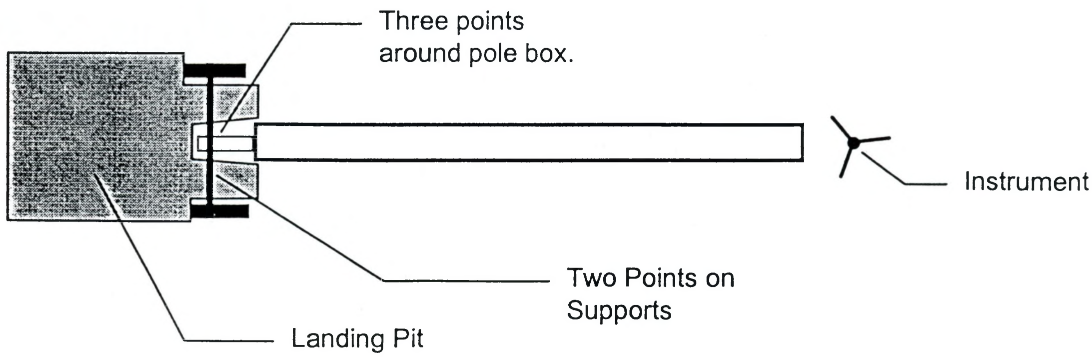
Once measured, results were transmitted to a Leica GPC1 hand held field computer. This device displayed the measurement to the judge while simultaneously forwarding it to the judge's electronic scoring system. Special low impedance transmission cables permitted RS232 communication at distances up to 150 metres without amplification. A full day's power for all components was supplied by a single 7 Ah NiCD battery.

A STABLE PLATFORM

In many events, the total station was mounted on a standard tripod. The tripod legs were firmly planted in the turf to provide a stable instrument platform. For the pole vault, long and triple jumps space and geometry necessitated instrument setups on the rubberized composite track surface, centimetres away from the athletes. Designed for world record 100 metre sprinters, the composite rubber surface was engineered to provide excellent rebound to an athlete's strides -- it appeared to be made of the same material as day-old Jell-O, causing the tripod to vibrate from the slightest touch. The solution to the problem included a heavy duty industrial QuickSet tripod with the tripod legs fully extended and a 20 kilogram weight suspended from the tripod center post for stabilization.

FIELD PROCEDURES – POLE VAULT

For geometry reasons, the pole vault required the most attention during setup and measurement. The instrument location was carefully selected to allow an unobstructed view of pole box, standards, and crossbar. The optimum location was found to be at the beginning of the runway. This location provided strong geometry for the solution, a clear view of all measurement points and had



minimum psychologic impact on the athletes. Anyone who has seen Sergei Bubka clear 6.09 metres (20 feet!) in the pole vault knows why the athletes cannot tolerate any disturbances. A spot too close to the landing pit made it difficult to sight the cross bar, locating far down the runway gave the best line of sight, but made communication with the judges difficult After selecting an instrument site, the tripod was installed and stabilized and the instrument mounted and leveled. Power was connected and the interface to the scoring computer was initiated.

Before the crossbar was raised, small (1 centimetre) reflective tape targets were placed on each of the crossbar support arms. The horizontal offset from the targets to the centre of the bar was measured and entered as a configuration parameter in the onboard software.

Immediately prior to the start of the competition, initial measurements were made to three points around the takeoff box. The three points determined a horizontal plane with height = 0. The automatic target recognition (ATR) system was used to give very fast, accurate observations

When the crossbar was raised, measurements were taken to the two reflective tape targets defining a vertical plane. The operator then sighted the lowest point on the top of the crossbar, which sometimes sagged 2-3 centimetre below the desired height. The instrument automatically computed the height of the crossbar above the ground. This result was sent to the hand held field computer where it was displayed and recorded by the judges. When the bar was raised or the crossbar shifted, the procedure of measuring the tape targets and crossbar was repeated, ensuring that any horizontal displacement of the uprights was considered in computation of crossbar height. Measurement time was normally under 60 seconds.

QUALITY CONTROL

Extensive testing was performed to ensure accurate and reliable performance of the Leica system. Procedures for the throwing and jumping events are well proven, and did not require extensive re-verification. The software and instruments were calibrated and compared against known baselines with excellent results. For the new approach to the pole vault, quality control and checking was extensive. The integrity of the mathematical model was tested and verified analytically before field tests were performed using conventional measurement techniques. Different configurations and instrument locations were evaluated, identifying some potentially poor instrument locations. During the test phase, the onboard software was revised to speed up the measurement process and simplify operation.

Hardware, software, and operators were thoroughly tested in advance of the competition resulting in a proven system exhibiting excellent repeatability and accuracy. All results were compared against IAAF regulations for track and field competitions. One of the more difficult tasks was educating the officials on the effects of 40°C heat and incorrect tension on a 100 metre steel tape. By strictly adhering to regulations and proving its accuracy, repeatability and robustness, the Leica system was unequivocally accepted by the officials.

SUMMARY

The systems performed flawlessly, immediately displaying results on the giant stadium scoreboard. The structured program of design, testing and system integration paid off. The IAAF officials were pleased and confident working with the system, another happy customer. A new technique was developed for measuring the pole vault remote height, a technique that may be useful for surveyors in the field. As a team member, it was a unique experience to see the athlete's results before anyone else. We all knew the world records in our events and we knew first when the records fell. Before the millions watching live coverage, before the judges, before the athletes. And we had fun.

Having finished my events for the Atlanta Grand Prix, I decided to watch the finals of the men's pole vault invitational. Sitting on the grass 10 feet from the landing pit and I saw Sergei Bubka clear a US record 19feet 11inches I realized this was going to be a very interesting summer. I actually started to worry that my boss would find out how much fun I was having and dock my pay. I knew I was safe when I remembered he was the operator for the pole vault and I saw him sporting an ear-to-ear grin. With Bubka attempting to go over the 20 foot mark, my boss really was measuring up.