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THE TRUTH ABOUT PROFILER"REPEATABILITY" TESTING AND THE IMPORTANCE OF ALSO TESTING A PROFILER'S ACCURACY

SSI presents this overview of the fundamental attributes of laser profiling system "repeatability" and "accuracy." An attempt is made to explain these concepts in simple terms to assist current and future owners and operators of laser profiling systems. There have been instances of false and deceptive advertising by one or more profiling system vendors seeking to sell equipment by focusing purchasers solely on profiler repeatability, while ignoring the issue of accuracy, which is actually a more important attribute of good profiler performance. The same profiler manufacturer(s) have touted fundamentally flawed research as evidence that their profiling system is "the best" or "the standard of comparison in the industry." Below SSI also presents comparisons of actual surface profile data generated from SSI and other manufacturers' profiling systems. We encourage readers to make their own informed decision as to the proof of *both* repeatability and accuracy of the SSI profiling devices, as compared to competitive systems. Interested readers can contact SSI for further information and proof of the superior performance attributes of SSI profiling systems.

1. Understanding the "Repeatability" of a Profiling System.

The essential performance capabilities of a laser profiling system can be assessed by evaluating both the repeatability and accuracy of the actual surface profile generated by the system. "Repeatability" is defined as how closely the profiles from multiple runs of the system over the exact same longitudinal surface match or compare. Assessing profiler repeatability is best done by comparing the profiles generated from numerous runs of the profiling device over a well-marked, stable surface. If the test surface has variations in its profile at different transverse points across the surface, a profiler's repeatability will be degraded, since a profile collected even inches apart from another may be significantly different. A test track that is consistent at various points transversely across the surface minimizes the risk that inconsistent tracking of the profiling vehicle will introduce errors into the repeatability comparisons. A test track that is well marked with paint dots or striping will assist the profiler operator with consistent tracking of the profiling vehicle. Having a mechanical lane tracking device (equivalent to a scope on a rifle) improves the profiler operator's ability to achieve consistent tracking of the profiling vehicle. Profilers designated for contractor and agency acceptance testing are usually not equipped with such mechanical tracking devices for safety reasons, as those devices constitute hazards extending outward from the front or side of the vehicle.

Repeatability can also be influenced by the filtering methods used by the profiling system manufacturer, or post-processing data filtering applied by agencies or researchers evaluating the profiler's data. Excessive filtering generally has a "smoothing" effect on the profile data that can cause multiple traces to be drawn closer together to artificially improve the appearance of the profiling device's repeatability. Over-filtering of profile data is seldom, if ever, a good practice.

2. Understanding The "Accuracy" of a Profiling System.

The "accuracy" of a profiling system is defined as the degree of agreement of the device's measured profile with an accepted reference or "true" value. Such reference values are typically generated by surveying instruments (e.g., rod & level) or inclinometer-based profiling devices (such as the Dipstick or some commercially available walking profilers). An assessment of a profiling device's accuracy can be quantified by a point-by-point comparison of the surface profile generated by the profiler with the data points from the reference profile.

A profiling system that is "repeatable" may not be accurate. In simple terms, consider each of several profile data runs generated by a profiler system as a dart thrown at a dart board. A "repeatable" profiler can cluster its darts closely together, but unless it is accurate, those darts miss the intended target. To score a bulls-eye (in this analogy) requires an exact match of the reference profile. A repeatable profiler that is also accurate clusters its data on top of the bulls-eye target by closely matching the reference profile. Figure 1 shows this analogy.

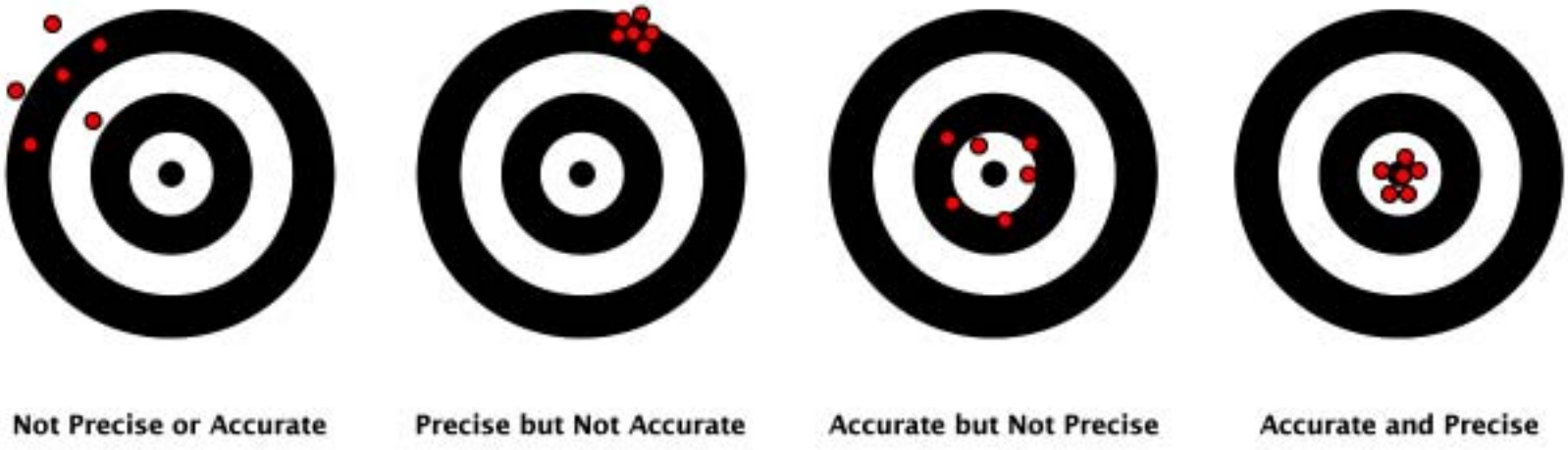

Figure 1--Profiler Repeatability & Accuracy: Dartboard Analogy

Thus profiler repeatability tests are entitled to little weight unless accuracy is also verified. Purchasers of profiling systems should beware of any manufacturer that advertises the so-called repeatability of their system without also demonstrating that its system demonstrated accuracy *on the same test track* as was used for the repeatability testing.

It is worth noting that some form of testing for both repeatability and accuracy is required under the widely recognized ASTM E-950 standard, and under the most stringent certification protocols for profiler certification (such as Texas DOT Test Method Tex-1001-S and AASHTO provisional standard PP51-02). Under these standards, the accuracy of pavement profile equipment is defined by concepts of "precision" and "bias." Precision (or repeatability), in the measurement of pavement profile, concerns the closeness of agreement between repeated measurements of the same pavement surface. To determine the "bias" (accuracy) of a profiler, ASTM E 950 uses a reference profile to characterize the systematic difference between the laser profiler's repeat measurements of a the same pavement section and the reference values at the same locations.

3. Proof of Repeatability and Accuracy of SSI's Profiling Systems Compared to Competitive Systems: Synthetic Bump Test.

SSI can demonstrate superior repeatability and accuracy of SSI profiling systems, as compared to competitive systems. As proof, we present some graphs of actual profile data showing repeat runs by both an SSI lightweight profiling system and a competitor system (rented by SSI) that has been advertised as the "best" based on flawed research that tested *only* repeatability. The first surface SSI used to test both profilers was a randomly placed artificial bump built to specific dimensions (eight feet in length, with incremental steps every 6 inches increasing up to 1.85" at the 4 foot length and decreasing back down to ground level at the end of the 8 foot bump). The exactly defined dimensions of the bump constitute a precise reference profile for accuracy testing. This synthetic bump is shown in Figure 2.

Figure 2: Artificial Bump for Testing Profiling System Accuracy in

The synthetic bump was placed at random locations on a well marked test track. Figure 3 shows overlays of the profiles generated by three repeat measurements of the bump by the competitor's lightweight profiling system. This graph shows fairly conclusive evidence that competitor's system is over-filtering its data to achieve better repeatability, but at the expense of accuracy. The competitor system erroneously detects the highest point of the bump by over .25" and errs in detecting the longitudinal position by at least two feet. These errors will cause significant difficulties for contractors, as the stations of localized roughness will be reported with a significant error.

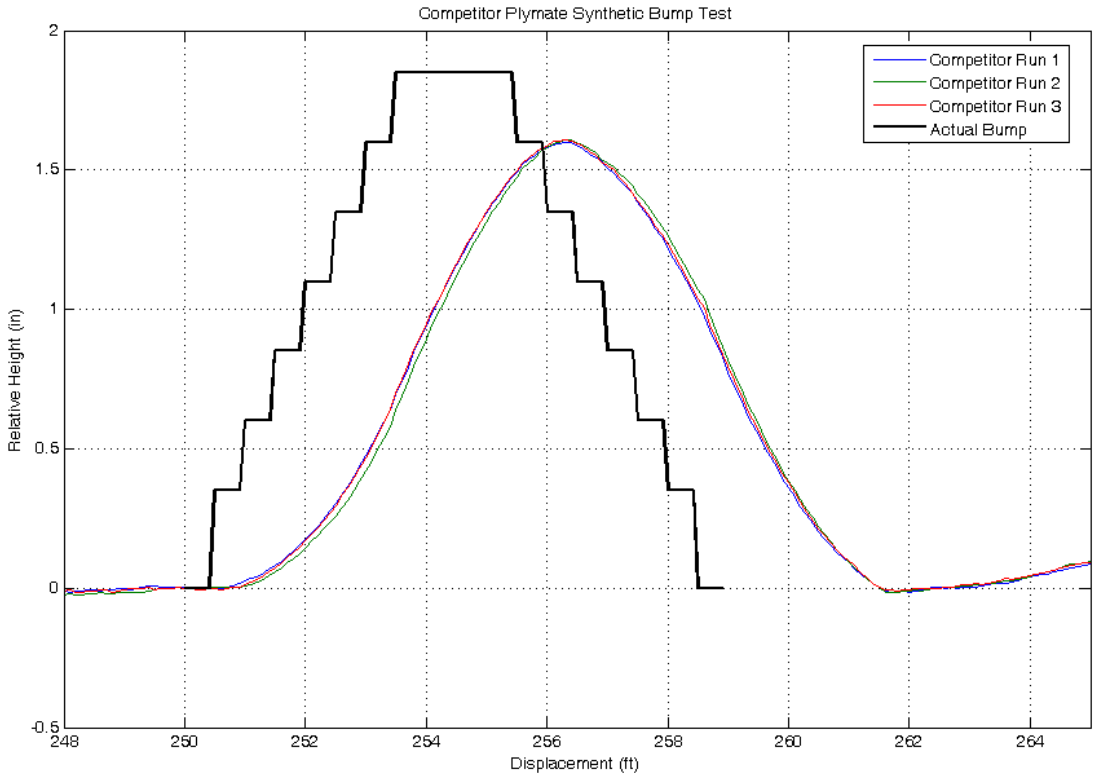

Figure 3: Competitor Lightweight Profiler Inaccuracy on Artificial Bump—Proof of Over-Filtering

Figure 4 depicts the SSI profiling system's data trace overlays of three repeat profile runs generated by an SSI lightweight system when run across the synthetic bump at the same location on the test track as shown in Figure 3 for the competitor system. This graph demonstrates superior accuracy over the competitor system, as well as excellent repeatability in locating the exact position of the bump throughout repeat runs.

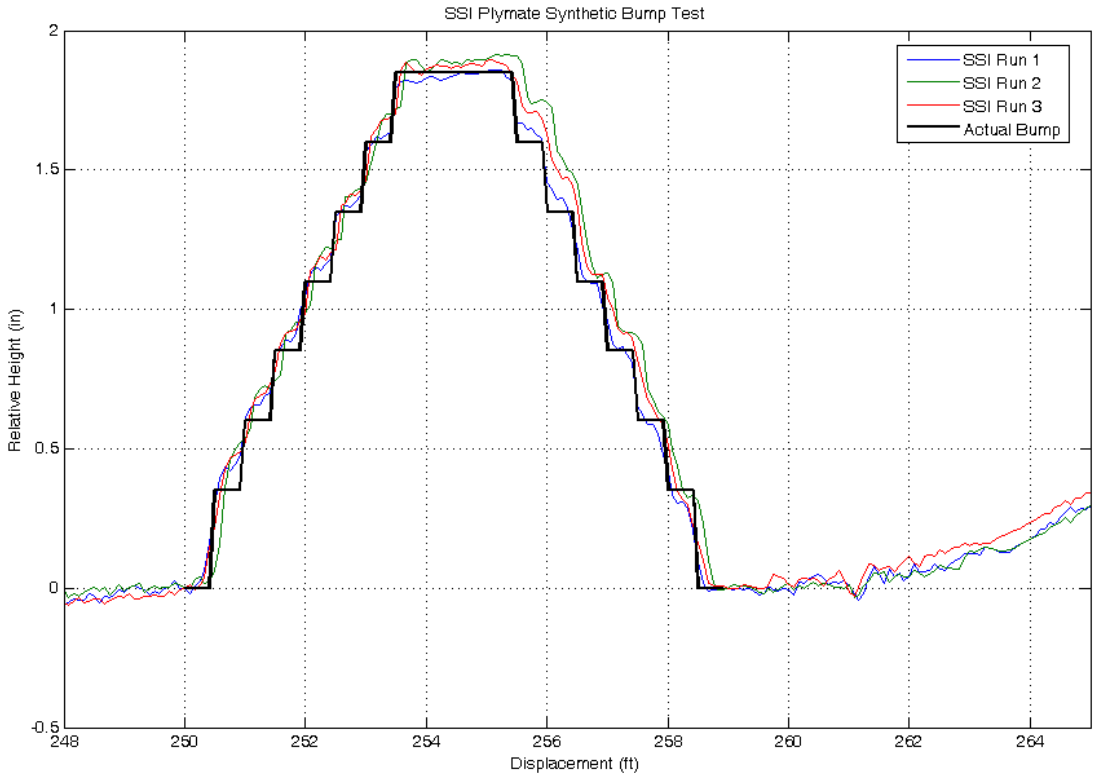

Figure 4: Proof of Accuracy of Data from SSI Lightweight Profiler on Artificial Bump.

The SSI system's high degree of repeatability and accuracy in detecting the exact dimensions of the bump is a result of the SSI system's digital electronics and proprietary filtering methods developed by SSI's engineers, several of which have PhD levels of education. The SSI system requires no excessive filtering to artificially enhance repeatability while degrading accuracy. Figures 3 and 4 emphasize that testing accuracy is of critical importance when testing profiler repeatability. Over-filtering enhances a profiling system's repeatability while degrading other more important measures of performance. Without a reference profile to keep profiling vendors honest, those undesirable activities go undetected by testing repeatability alone. However, most state certification procedures increasingly require some form of accuracy verification. For these reasons, a profiler manufacturer boasting repeatability alone cannot be trusted without proof of accuracy on the same test data.

It bears emphasis that profiler manufacturers have the ability to apply excessive filtering to effectively "smooth" their profiler's data in order to tighten the repeatability of test data, but unless that data is compared to independent reference profile, the decreased accuracy caused by excessive filtering is hidden. Note the smooth character of the traces in Figure 3, which is a result of excessive filtering. This presents a significant risk of liability to contractors, as oversight agencies will penalize contractors for using devices that are found to erroneously report ride quality results or

localized roughness. As certification procedures evolve to require testing of both precision and accuracy, the practices of vendors who are excessively filtering their profiler's data will be revealed and forcibly changes. SSI is currently undertaking to inform DOT agencies of the impacts of excessive filtering by particular profiling systems. DOTs should verify the accuracy of profiler data by (1) verifying the profile index calculations (PRI, IRI, etc.) with independent software (e.g. ProVal), (2) comparing the actual profile traces from different devices for equivalent detection of localized roughness (must grind-bump and dips), and (3) comparison of the profiles generated by each system with an independent reference profile (again using neutral software, such as FHWA's ProVal).

4. Proof of Repeatability and Accuracy of SSI's Profiling Systems Compared to Competitive Systems on a Marked Test Track.

SSI conducted additional repeatability and accuracy testing by collecting multiple data collections on a well marked test track for which a reference profile was also collected. This type of testing allows assessment of profiler performance under the most stringent profiler certification requirements currently enforced in the industry, Texas DOT Test Method Tex-1001-S and AASHTO provisional standard PP51-02, which the SSI systems pass by a substantial margin. The tests consisted of fifteen data collection runs by an SSI lightweight profiling system, and the system (rented by SSI) of a competitor who falsely advertises that its system "sets the standard for lightweight profilers" and "simply produces the most accurate profile of any lightweight profiler on the market." Key notes regarding the test track and operation of the profiling systems are as follows:

- Well-marked, clean test track with control markings established with periodically spaced paint dots to allow consistent wheel path tracking of the profiling vehicle.
- Separate Dipstick and walking profiler reference profiles at data sampling intervals down to 1 inch (25 mm).
- Both profiling system were driven by the same experienced operator following manufacturer's recommended operating procedures.
- Both systems were configured as supplied by the manufacturer (with neither having the advantage of a mechanical lane tracking device used by some vendors when participating in research testing).
- Test run data from both profiling systems was filtered using the manufacture's standard settings and converted to ERD formatted data for post-processing by FHWA's ProVal public domain software.

Figure 5 shows overlays of the best nine of fifteen runs from the competitor profiling system, while Figure 6 shows overlays of the best ten of fifteen runs from the SSI systems. (Only nine runs were overlaid from the competitor system, since the use of ten or more runs significantly worse repeatability and accuracy). Comparing Figures 5 and 6 reveals excessive noise in the trace and significantly poorer repeatability of the competitor system as compared to the SSI system. Figures 7 and 8 add the overlay of the reference profile as generated by the Dipstick device. These figures show much better accuracy by the SSI system in generating repeat runs that more closely match the reference profile. The SSI system demonstrates a superior ability to achieve reproducibility of the reference profile of the test surface run after run.

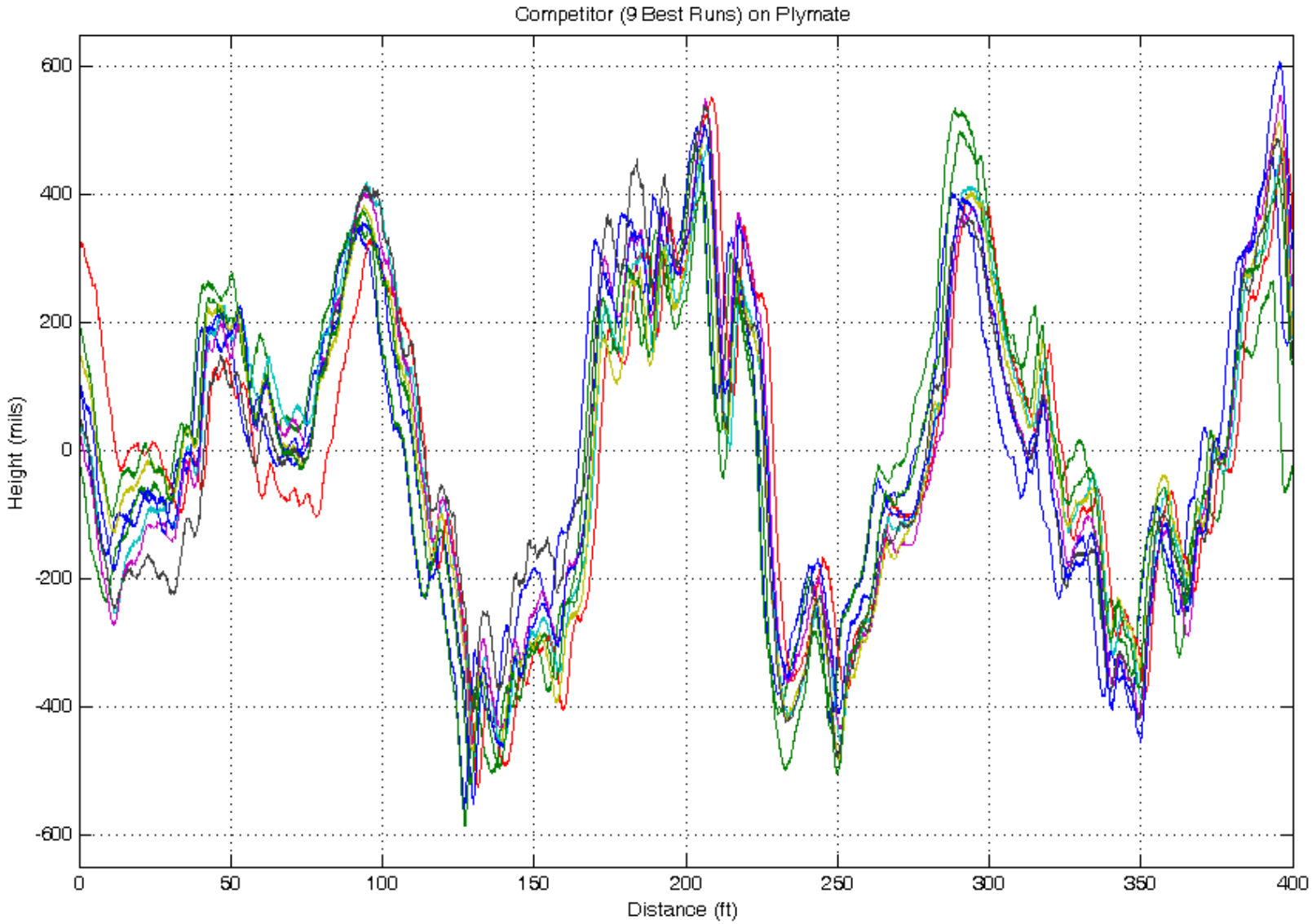

Figure 5: Trace Overlays from Best 9 of 15 Runs By Competitor Profiling System on Well Marked Test Track..

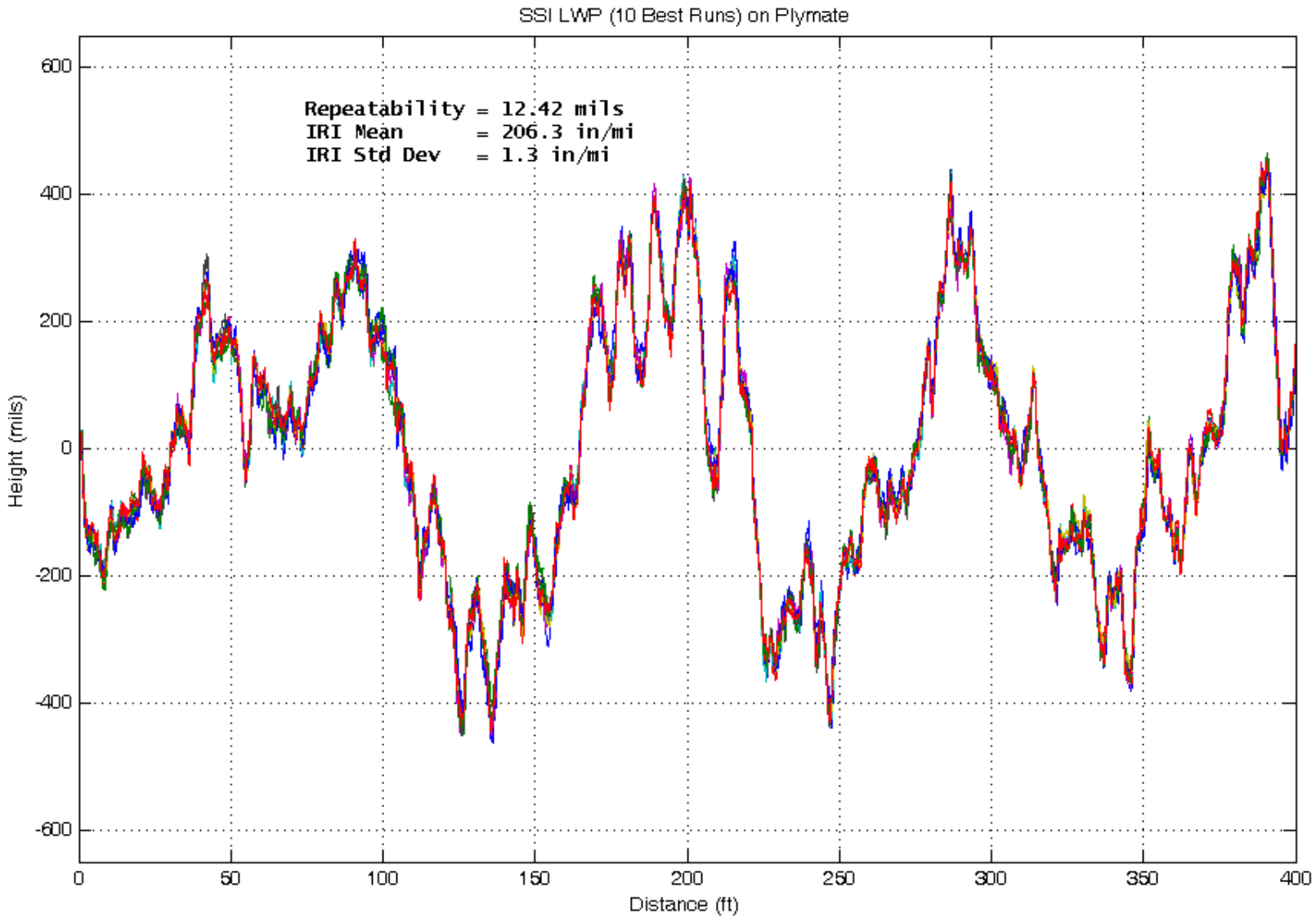

Figure 6: Trace Overlays from Best 10 of 15 Runs By SSI Profiling System on Well Marked Test Track..

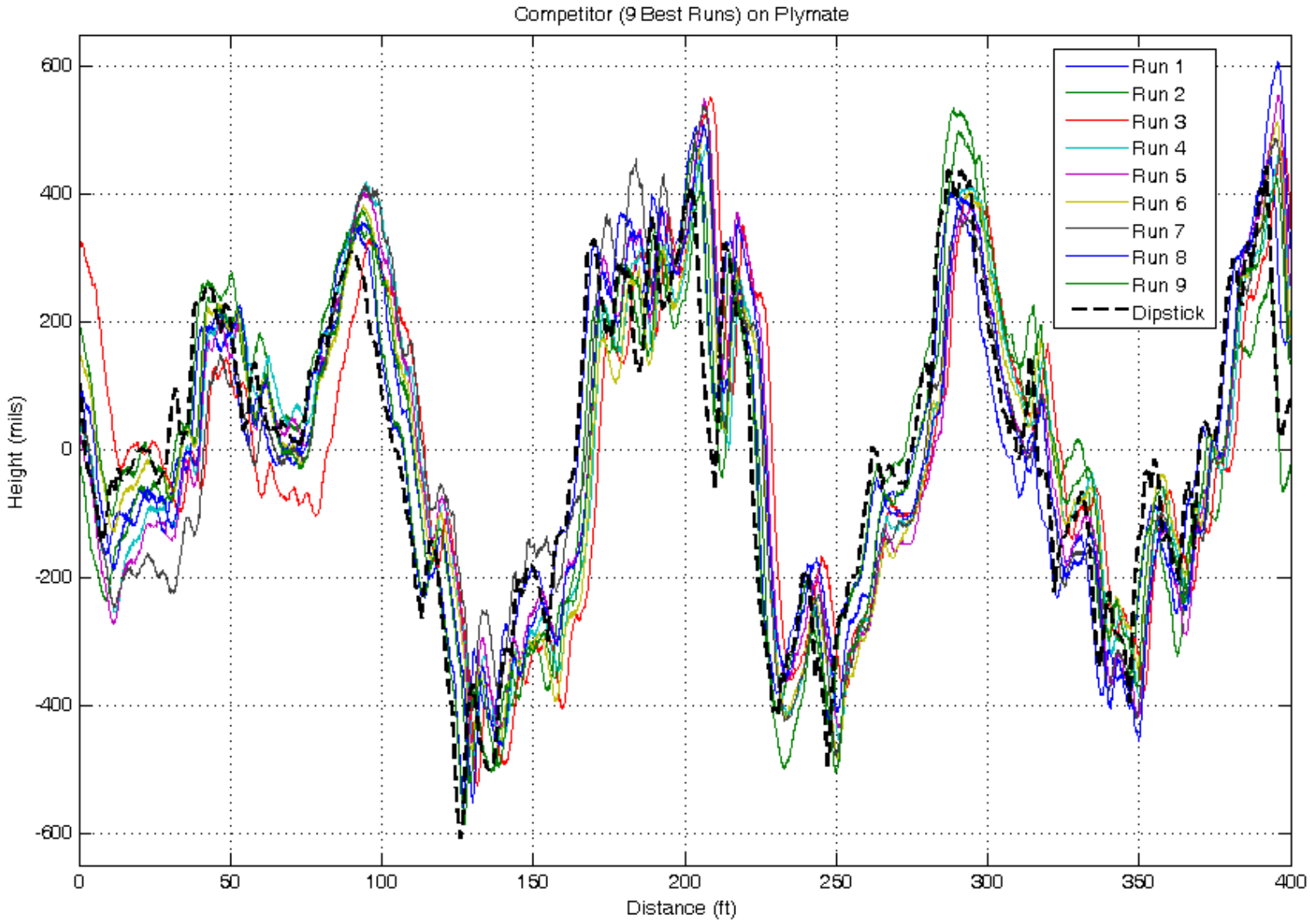

Figure 5: Adding Reference Profile Comparison to Best 9 of 15 Runs By Competitor Profiling System on Well Marked Test Track..

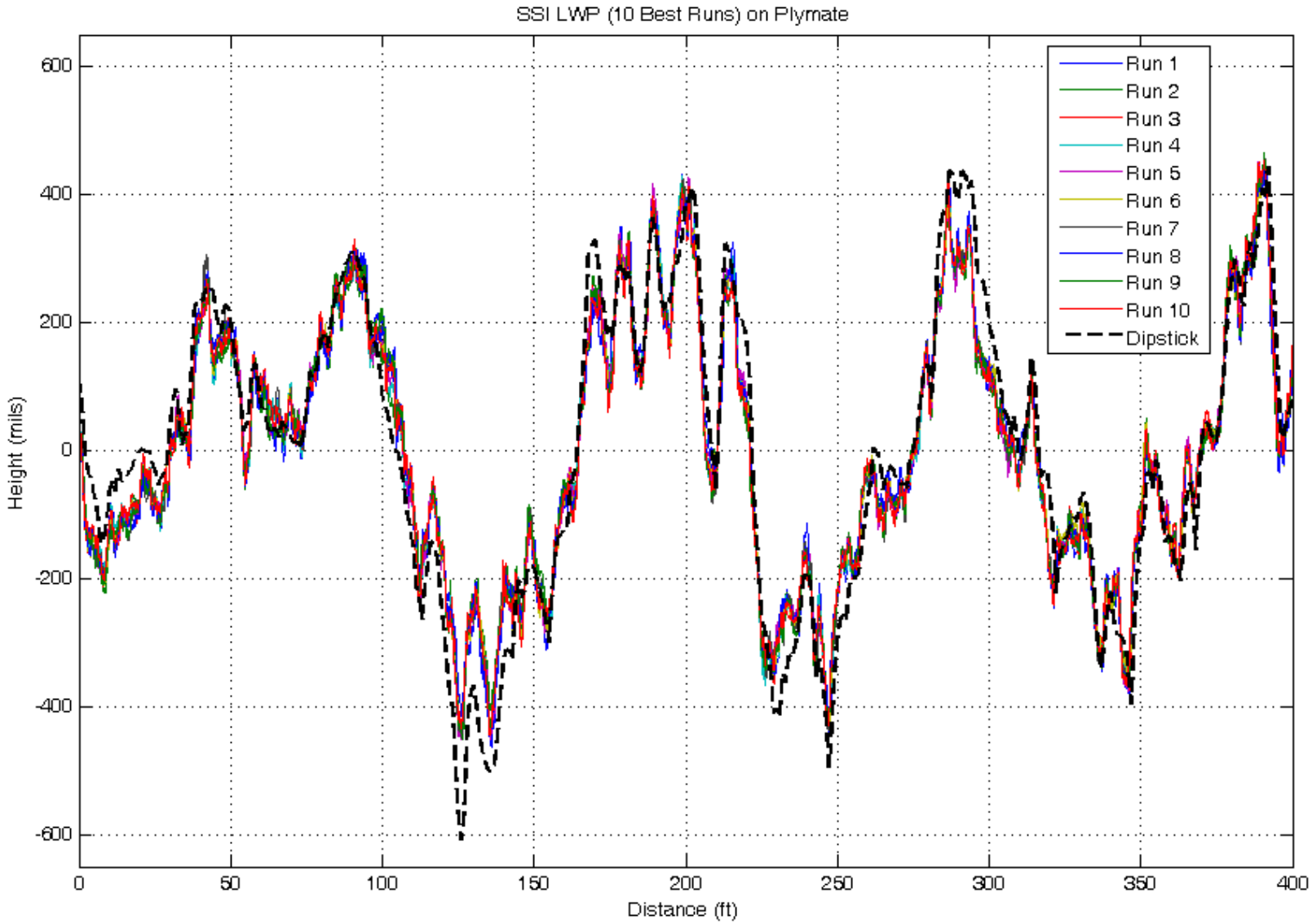

Figure 5: Adding Reference Profile Comparison to Best 10 of 15 Runs By SSI Profiling System on Well Marked Test Track..

5. Summary

As a responsible manufacturer of road surface test equipment, SSI has published this document to help educate readers about repeatability and accuracy as two independent, critically important attributes of profiling system competence. SSI also hopes that this presentation will discourage further dissemination of false or deceptive advertising representations by other profiling system manufacturers. The test data is presented as proof of the repeatability and accuracy of SSI's profiling system, as compared to the competitive system whose data is also presented. SSI encourages readers to draw their own conclusions as which profiling system produces the most repeatable and accurate profile data. For further information, please contact SSI at info@smoothroad.com or by telephone at (800) 662-5656 or facsimile at (415) 358-4340.