Review, Analysis and Criticism of the Report by Michael A.G. Clark, Ph.D.:
***"Technical note: Unreliability of Laser Speed Meters"* (Issue 1, Copyright 2005)**

prepared by

Daniel Y. Gezari, Ph.D.
Chevy Chase, MD

for

Laser Technology, Inc.,
Centennial, CO

Introduction:

I have reviewed the technical report, *"Technical Note: Unreliability of Laser Speed Meters"* (Issue 1 Copyright 2005) by Michael A.G. Clark, Ph.D., at the request of Laser Technology, Inc. (LTI), Centennial, Colorado, manufacturer of the LTI 20-20 series infrared laser speed measurement instruments. This document summarizes my reactions to that report.

Clark begins with a general statement which sets the tone of the report. He is trying to leave the reader with the impression that laser speed meters are: 1) unreliable, 2) inaccurate and 3) easily mishandled 4) prone to producing incorrect results and false measurements, and that 5) these failures would be frequently encountered in routine traffic law enforcement applications. The first paragraph of Clark's report states:

> "Speed measurements of vehicles taken using laser speed meters have been found to be unreliable. Measurement errors occur for a variety of reasons. This document explains how these happen, and describes tests that have been conducted to demonstrate the different mechanisms involved."

Clark would have us believe that laser speed meters (in particular the LTI 20-20) are so prone to producing erroneous results that the instruments malfunction more often than not. His purpose here seems to be to make the exception appear to be the rule. In fact, anomalous results are extremely rare and difficult to obtain with the LTI 20-20, so much so that an operator of the instrument who was not familiar with the failure modes that Clark alleges would have to be instructed in the particular techniques that should successfully produce errors, and would also have to practice the precise moves that are required. When used by trained operators, under normal operating conditions, and according to the manufacturer's instructions laser speed meters are accurate and very reliable.

PART I: GENERAL IMPRESSION OF THE REPORT

Scientific Method:

Clark's overall approach violates many of the traditional rules of scientific investigation. He sets out with the intention of achieving a particular preferred outcome. He also selects among the results for evidence that favors his hypothesis, and he ignores, discards or omits results that conflict with it. He avoids the normal operating procedures that a trained operator would use in making such measurements. He stages carefully prepared demonstrations in place of what is needed, which would be a careful and objective scientific analysis of the accuracy of laser speed measurement devices such as the LTI 20-20.

A scientifically rigorous experimental approach would be to take a statistically significant number of speed or distance measurements of moving vehicles, under realistic road and traffic monitoring conditions, using procedures that are appropriate to the measurement, as would a competent operator who had no motive to achieve a predetermined result. The vehicles would be observed in typical traffic conditions (both freely flowing and congested), and at different known or independently determined speeds. The measurements obtained by the laser speed meter would then be compared with the true speeds and distances of the target vehicles in the sample. This is how the laser speed meters are tested for approvals throughout the world.

Clark's technical report does not conform to accepted scientific standards and practices. But to be fair to Clark, we should note that he never claimed that there was anything scientific in his experimental approach. The report is anecdotal: No quantitative details are provided, no statistically significant data seems to have been acquired, and no statistical analysis of data is presented. No technical or scientific reference sources are cited. No supporting or related experimental work is cited. No supporting results by others are cited. No conflicting experimental results by others are discussed or refuted. No alternate explanations are considered.

If the LTI 20-20 was found to produce inaccurate results in the application and under the conditions for which it is intended to be used, and when using the simple procedures and calibration techniques specified and recommended by the manufacturer – in a statistically significant number of measurements – then there might be reason for concern. But Clark has chosen to take a much less rigorous approach. The net result does not constitute a scientifically sound or compelling argument that the LTI 20-20 is inaccurate or unreliable.

Experimental Approach:

Clark's demonstrations take place outside of the normal operating parameters of the intended application, ignoring or intentionally disregarding the basic procedures and conditions recommended by the manufacturer.

Clark's demonstrations of anomalous events are conducted under specific conditions that are unlikely to be encountered in a legitimate traffic law enforcement situation. Anomalous results would rarely be obtained by an operator who did not have prior knowledge of the specific techniques and circumstances that can induce unreliable results with laser speed measurement devices. In reality, an unbiased, honest, and competent operator of the LTI 20-20 would essentially never obtain the kind of false positive results that Clark leaves the reader to imagine are commonplace. With only the most rudimentary knowledge of instructions for its intended correct use, a sensible operator would consistently obtain valid results. Yet Clark represents these anomalies as so easy to obtain accidentally that they would render the instrument unreliable in ordinary traffic law enforcement applications.

In his demonstrations, Clark has to be careful to use specific, unusual techniques in order to successfully force anomalous results. For example, one video clip shows an operator producing false positive speed measurements by observing the surface of the road. However, if you look closely, you can see that the operator is aiming the red dot at the narrow white line along the edge of the roadway, and smoothly panning that red dot carefully along the line. The white line is a special reflective paint that efficiently reflects light directly back in the direction from which it comes (the same kind of reflective material used on license plates and roadside traffic signs to improve their visibility at night), This reflective paint would provide a much stronger return signal than the bare road surface. Without panning very carefully along the reflective painted line, but simply performing the same panning maneuver directly on the plain road surface, the returned signal would be too weak to produce a viable data set that would satisfy the error trapping criteria. No calculation would be made, and no result would be displayed.

The same kind of favorable circumstances are employed in another demonstration, were the operator obtains a false speed measurement from a stationary wall. The impression left by the demonstration is that panning the beam against any flat, stationary surface will easily produce a false speed measurement. In this case, however, the wall appears to be made of corrugated sheet metal, which has numerous regular facets. The corrugated material can significantly increase the back-scattering efficiency of the surface, and thus increase the strength of the laser beam reflected back to the gun. It would be much lore difficult to obtain a false speed reading when targeting an ordinary, flat, non-reflective surface compared to the exceptional case of the corrugated wall that was chosen in the demonstration. A non-expert reader would probably not realize that the corrugation of the wall contributed significantly to the success of the simulation. Of course Clark did not mention that the wall could have a more efficient back-scattering surface, or that achieving the anomalous result might have been impossible if a flat metal, wood or masonry wall were the target.

Clark does not point out how difficult it is to obtain false results with the LTI 20-20, or how infrequently they occur, even when an operator with prior knowledge deliberately attempts to induce them. Nor does he describe how delicate and precise the specific motions have to be to produce those errors. Even with determination and prior knowledge, such errors are produced only a small fraction of the time.

It is apparent from watching the DVD that accompanies this document that many of the operator's attempts to produce incorrect results are themselves failures. When the operator tries to produce a false result, error messages often appear repeatedly on the LTI 20-20 display (E2, E3, etc., etc.) before a false reading is finally induced. Although the operator is making a concerted effort to induce some false effect or inaccurate result with the instrument, and has been instructed in how the trick should be done, the initial attempts to produce a false result are unsuccessful. His attempts to obtain anomalous results are plagued by frequent error messages because of rejection by the error trapping algorithms (which is the correct response of the LTI 20-20 when unreliable or corrupted data are acquired), and numerous *correct* results, which of course were not the objective of Clark's study.

Quantitative Analysis:

Clark does not support any of his claims with statistical information. His report lacks any reference to the statistical likelihood of obtaining false-positive results that would in any way compromise the integrity of the laser speed evidence. A failure report that is presented without any quantitative data or statistical analysis has little technical or legal force.

It would have been quite compelling criticism of the LTI 20-20 if Clark had been able to make a statement such as this:

> *We arranged to have properly trained and qualified police officers make 1000 separate measurements of the speed of motor vehicles, under normal traffic flow conditions similar to those that are found on our domestic highways. Those officers were unaware of the purpose of our tests. The results were troubling. We obtained many false and inaccurate readings: Of the 1000 measurements that were made, 500 produced error messages, 350 produced false positive speed readings, and only 150 produced accurate results.*

But Clark made no such statement, which might have clearly defined the statistical significance of his findings.

In contrast, if a scientific test of the LTI 20-20 was conducted in a typical law enforcement setting, and the data were presented in a statistically useful form, the results would most likely be correctly described by a statement such as this:

> *Of the 1000 measurements that were made by qualified officers, 950 produced accurate results, 50 produced error messages (with no displayed speed result), and none produced false-positive, incorrect or anomalous measurements that exceeded the manufacturer's specified accuracy for the device."*

This statement is a realistic characterization of the performance of the LTI 20-20 in the application for which it is intended.

Significant Omissions:

Clark does not mention many facts and many factors, which I assume he is aware of, which would significantly undermine his case. As one randomly chosen example of significant omissions in his report, Clark goes through pages of test descriptions without mentioning that the measurements were made while targeting the *side* of the vehicle.

For completeness and accuracy, Clark probably could have (and perhaps he should have) said all of the following things about his technical approach and analysis:

1. We have not tested or inspected the particular device that was used to measure the speed of our client's vehicle, so we don't know if it can be induced to produce these failures.

2. We have never done a statistical, quantitative analysis of the accuracy any one LTI 20-20 device, or among a group of those devices.

3. We have never reported the results of a test of the LTI 20-20 device in the normal application for which it was designed.

4. We have never reported the results of a test of the LTI 20-20 device under the kinds of traffic, environmental and weather conditions in which it is intended to be used.

5. We have never reported the results of a test of the LTI 20-20 device under the specific conditions and situations that replicate those that existed when our client was measured to be exceeding the speed limit.

6. We have never published the results of any test of the LTI 20-20 device in a professional science or engineering journal.

7. We routinely demonstrate the LTI 20-20 device under conditions and in situations that directly conflict with and disobey the manufacturer's instructions, recommendations, and guidelines.

8. We routinely demonstrate the LTI 20-20 device only after we have deliberately misaligned and/or de-calibrated the instrument.

9. We have not reproduced any of the alleged failures under normal use by an objective operator, and in realistic traffic speed measurement situations.

10. We are unaware of any reports by others of any such failures having occurred under normal use by the police in an actual traffic speed measurement.

Logical Argument:

Clark's case against the LTI 20-20 seems to rely heavily on semantic technicalities and selective omissions. He tends to use strong words for effect when they further his purposes. For example, the word “more” is true whether it is 1% more or 10 times more; the word “exacerbates“ is true, whether the result is negligible or dramatic. The reader is left to assume that if the word is used there must be a good reason for it, however, using the reader’s assumptions to build a case against laser speed measurement is hardly a rigorous approach to technical analysis.

Clark’s basic argument is that if he can produce false-positive results by controlled means, and in unusual circumstances, then those same errors must be obtainable accidentally during routine and proper use of the device in its intended application. But Clark has not shown that any accidental errors have ever occurred during standard use of the instrument. He has only shown that errors can occur during intentional mishandling and abuse of the device. Clark would have to do intensive testing in a real traffic monitoring environment to claim anything about the reliability of the LTI 20-20 for measuring vehicle speeds.

There is nothing biased, dishonest or unethical in attempting to identify flaws or weaknesses in the design or application of a scientific instrument, or to demonstrate the frequency with which an unreliable or incorrect measurement can be obtained with it. However, a study would lack objectivity if the results were selected to support a particular hypothesis, or if information that is consistent with the hypothesis was presented, while other information that contradicts the hypothesis was suppressed.

Professional Qualifications:

I have no specific, factual reasons to doubt Clark’s claims as an expert in this field, or his description of his academic experience. We must assume that he has represented himself honestly. Yet, based on the tone of his report, I am left feeling uneasy and skeptical of Clark’s professional qualifications, and his claims of advanced academic credentials.

The style of Clark’s campaign to discredit laser speed measurement in general, and the LTI 20-20 device in particular, does not reflect the kind of scientific rigor and objectivity that are naturally acquired in the course of a good graduate science/engineering education. His experimental approach, and his style of reporting his results and conclusions, are inconsistent with the work of a person with extensive experience in a formal, scientific laboratory setting.

Experimental physics and engineering are highly disciplined fields, with clear rules, procedures and standards of analysis. Clark’s work reflects none of those requirements and standards. His experimental approach and his logic are peculiar, and seem to lie somewhere outside the mainstream of professional scientific experimental culture.

The following specific issues make me feel skeptical about Clark's true qualifications as a laser speed measurement expert.

1. Clark does not identify the institutions at which he received his education, or the specific academic degrees and dates received. He claims to “hold the degree of doctor of philosophy in the field of lasers and electronics." He claims that his “first degree is in electronic and electrical engineering”. From which institutions did he receive his advanced degrees? What were names and dates of those degrees?

2. Clark claims to be a Fellow of the Institution of Electrical Engineers and a Fellow of the Institution of Highways and Transportation. What are the requirements for membership in these two organizations? Must one be a professional engineer? Must one be a researcher in those fields? Or, must one simply pay for membership dues and a magazine subscription? It would be useful to answer these questions.

3. A Google search of the name “Michael A. G. Clark” yields no results. A search in Google Scholar yields six results, all patents that Clark holds, but no published professional papers by him, and no references to any of his work by others.

4. Clark claims to be the UK representative expert on the European Standards Committee for Vehicle Detectors, and says he was elected chairman of that international committee. Is this true?

5. Clark claims to be a specialist who has advised the UK government and private companies, and states that this includes advice to a private company concerning a replacement speed enforcement system for the M25 highway in the UK. Does Clark's business interest in supporting a system to replace the LTI 20-20 constitute a conflict of interest that might motivate his aggressive attacks on the LTI 20-20 in the public media?

As an example of the way I would like to see Clark present his qualifications, I can describe my own:

I received the A. B. degree in Physics from Cornell University in 1966, the M.S. degree in Physics from New York University in 1969, and the Ph. D. degree in astrophysics from State University of New York (Stony Brook) in 1973.

I was a post-doctoral research fellow in the Physics Department at the California Institute of Technology 1974-1976.

I was a National Research Council Resident Research Associate 1976-1978, and

Astrophysicist at NASA/Goddard Space Flight Center 1978-2006.

In 1989 I received the NASA Medal for Exceptional Scientific Achievement for my work in the application of infrared detector systems in astronomy.

I am now Emeritus Astrophysicist (retired) at NASA/Goddard.

I would also describe in detail my experience as a research scientist in infrared imaging instrument development and its application to infrared observational astrophysics, my work with lasers in optical image processing, and provide a list of my relevant scientific and technical publications.

I would also summarize my private work as consulting physicist and engineer in optical instrumentation and medical equipment design, my experience as an expert witness in a dozen court cases involving laser speed measurements, and the eighty-page chapter I wrote on “Laser Speed Measurement for Traffic Law Enforcement” for a legal compendium (all available on request).

PART II: SPECIFIC COMMENTS ON THE CONTENTS OF THE DOCUMENT

Subject heading – "Introduction":

The introduction to the document contains a two page general description of the displays and user interface of LTI 20-20 instrument. Beyond that, nowhere in the document is there any description of the technical or performance specifications of the LTI 20-20, or the principles, technology and design of the instrument. There is no discussion in the report of the principles of the LTI 20-20 measurement, the techniques used in data acquisition, data analysis and error trapping, the sensitivity of the instrument, or the accuracy and repeatability of the displayed results. The absence of any reference to all of these fundamental technical topics is a major deficiency of Clark's report.

Subject heading – "Alignment":

Item 25… Clark states that there are two alignments that must be carried out for proper use of the instrument: First, alignment of a red dot in the scope to the laser beam, and second, alignment of the crosshairs in video camera with the red dot. He goes on to say: "These alignments are crucial. If they are not correct then the laser beam is not striking the area shown on the video crosshairs". There are two separate alignment concerns being expressed here. One is whether the laser beam will strike the point on the vehicle that the operator has chosen, and the other is whether the video camera shows an accurate view of what the operator sees in the scope.

[Note: The video camera is not part of the LTI 20-20 instrument. It is a separate piece of equipment that the UK police use for documenting the circumstances of the measurement.]

Clark states further that "if the scope alignment is not correct then the laser beam is not striking the area shown in the video by the crosshairs." Clark leaves the reader to assume that there is something about the laser alignment with the video crosshairs that affects the speed measurement. The video simply provides a record of which car is being targeted, the roadside scene, the position and movements of the operator, the light, visibility and weather conditions, etc. The video crosshair alignment has no bearing on whether the red dot in the sighting scope is correctly aligned with the laser beam. It simply means that the view displayed in the video record is the same as the view observed by the operator. The camcorder identifies the target vehicle, but it does not contribute to the measurement of the speed or distance of that vehicle. While it is important that the view in the camcorder be a good representation of the scene, it has only secondary value because the red dot that the operator sees in the sighting scope is not recorded by the camcorder.

What is more important is that the red dot in the sighting scope be an accurate indication of the position of the invisible laser beam in the targeted scene. If the dot and the laser beam are correctly aligned with the operator will measure the speed of the specific part of the target that he aims at.

The sighting scope is a zero-magnification (1:1) device so the scene is not altered when viewed through the scope. The field of view of the scope is about 8 degrees, which is about 50 times the angular width of the laser beam.

Scope alignment is not a delicate or sensitive adjustment. A significant change of the position of the red dot relative to the position of the laser beam can only be obtained only by several turns of the adjustment screw. Moving the red dot from the center to the edge of the scope takes about 4 full turns of the adjustment screw. In contrast, re-alignment after a daily alignment check might require only at most about ¼ turn of the adjustment screws, so small motions of the screw have negligible effect of the alignment. It is important to note that most operators do not find any misalignment during the daily alignment check, and therefore that the alignment screws are rarely ever used.

It is easy to achieve and maintain good alignment. It is easy to ensure proper alignment of the red dot with the laser beam using the simple alignment procedure specified by the manufacturer. Alignment of the red dot and the laser beam is extremely simple and the outcome is unambiguous. It takes no effort or attention to maintain good alignment. The LTI 20-20 designed and constructed so that it is simply not prone to drifting out of alignment.

At the same time, the alignment is not easily degraded by casual or rough handling of the instrument. Setting the gun down, picking it up, etc., would not cause any misalignment to occur. In fact, even dropping the instrument on the ground would not necessarily result in a misalignment. A significant misalignment might possibly result if the instrument were subjected to extreme abuse (for example, if it was dropped or thrown from a moving vehicle). Only damage resulting in mechanical deformation of the chassis would be likely to affect the basic alignment. Routine, even rough handling does not raise any alignment concerns.

The LTI 20-20 does not exhibit any tendency to drift out of alignment with time. The daily alignment check is simply performed for good scientific and legal practice, to ensure that the device is known to be in working order and is capable of producing accurate results at the time that the measurement is made. This is to ensure both the scientific and legal integrity of the results. It allows the operator to testify honestly, from personal experience, that the instrument was in good working condition at the time of the measurement.

Despite the inherent immunity of the LTI 20-20 instrument to misalignment, Clark tries to give the impression that the alignment is unstable, and that the slightest misalignment will destroy the integrity of the measurement.

There are several examples in the TV shows where the scope would have to have been grossly misaligned. In one demonstration it is apparent from the way the operator repeatedly obtains a false-positive result that the laser is a beam is falling entirely outside the field of view of the finder scope. It would be practically impossible for a gross a misalignment of this kind to occur by mishandling, negligence or as a result of a casually performed daily alignment check. The only way to produce the kind of false positive results that Clark attributes to misalignment would be if someone moved the red dot out of alignment to its extreme limit of adjustment, but Clark does not state how many turns of the adjustment screw or how many degrees he deliberately misaligned the scope to produce the false results in the TV demonstration.

Subject heading – "*Tests*", Sub-heading - "*Beam Spread*":

Clark devotes about one page to a description of the beam pattern of the LTI 20-20, and the possibility that more than one target will be covered by the beam of the device. He points out that the manufacturer's specification for the beam width is 3 milliradians, about 0.17°, which corresponds to about 1.2 m at a distance of 400 m.

Clark goes on to say that the LTI 20-20 always acquirers the closest target, which he claims raises the concern that if two vehicles are in the beam, the LTI 20-20 will record the distance and the speed of the closer vehicle. However, according to the specifications that he mentions, the targets would have to be perhaps as far away as one-mile for the beam spread to cover both of them. Furthermore, if two vehicles do appear in the beam, and two different signals are returned, the error-trapping software will detect and reject the measurement, no speed calculation is made, and only an error message is displayed.

Clark refers to discussion on the Internet where the LTI 20-20 is described as “more like a shotgun than a rifle.” Of course, one of the key characteristics of the LTI 20-20 is the narrowness of the beam. For example, the LTI 20-20 laser beam is about 100 times narrower than a radar traffic speed gun beam, so the LTI 20-20 is certainly more like a "rifle" compared to the radars speed gun, which could easily be described as a "shotgun".

Clark describes how he photographed the infrared laser beam of the LTI 20-20, as projected on a wall, using infrared sensitive film, and that it showed three beams, not one. He claims that the laser beam has two side lobes that are outside of the specified beam width, and therefore that this could result in the wrong vehicle being targeted. Both these claims are false. What Clark did not mention (and perhaps what he was not aware of) is that the 3 millirad beam width specified by the manufacturer is the width of the three beams together (considered as a single beam), not simply the width of the central beam.

Item 35… Clark makes the statement that the LTI 20-20 always acquires the closest target that it can "see". What Clark apparently means here is that the LTI 20-20 will always measure the distance and the speed of the closest target went to targets are present in the beam.

Item 37… Clark goes on to say, "This shows how a distance and hence a speed can be ascribed to the wrong vehicle, even when the LTI 20-20 has been correctly aligned." In fact, the LTI 20-20 will only measure the speed of the target that the narrow laser beam illuminates. If the operator aims the device at a crowded field with multiple potential targets in it, this would violate the manufacturer’s instructions and guidelines for the use of the instrument.

The manufacturer’s guidelines say that the measurement should and should be made in a location from which there is a clear and unobstructed field of view, and that the target should be isolated and easily identifiable among other targets in its vicinity. This is not only the recommended operating procedure, it is plain common sense. The operator is trained to recognize that measurements made in a cluttered field containing multiple potential targets would be of little value if introduced in a court of law, and thus the operator doesn't waste his time making observations under those circumstances.

Subject heading – "Misalignment”:

There is a serious, pervasive weakness of Clark’s report: a lack of any *quantitative* information in the claims made, tests described and examples presented.

Item 42… Clark states, "For this test the red dot was deliberately, *but only slightly* misaligned as indicated in image 21", and he then proceeds to describe false results that he obtained. How much is "only slightly" in this case where the laser beam and the sighting scope were intentionally misaligned? Does it mean 0.1°, 1°, or perhaps 10°? The term "only slightly" is so vague that it has no meaning in this context. Clark seems to be implying that the slightest misalignment between the laser beam and the sighting scope can result in frequent, incorrect speed or distance measurements.

Image 21 at the back of the report is a simple sketch that illustrates the laser beam misaligned with the direction of the centerline of the sighting scope. In this artist's sketch the laser beam and scope are shown to be misaligned by about 30°, an extreme exaggeration. In this case, the reader might well get the impression that it is possible for the laser beam and the sighting scope of to be out of alignment by as much as 30°. In the same illustration the laser beam is depicted as being perhaps 5° wide when, in fact, the true beam width is only about 0.2°. So the beam shown in the illustration is drawn perhaps 25 times wider than the actual beam width of the real LTI 20-20 instrument. By presenting a continuous stream of exaggerated and technically inaccurate diagrams and photographic examples, Clark establishes in the mind of the reader a distorted scale of sizes, angles and orientations. Within this distorted perspective Clark eventually creates an impression in the mind of the reader that major failures of the instrument can be a common

Item 44… Clark suggests that a speed measurement can be ascribed to the wrong vehicle when the LTI 20-20 is only slightly misaligned, and that a misalignment of only 1° will result in an offset of 3.5 m at a range of 200 m. To a non-expert 1° might seem to be a very small angle. However, even a casual attempt to align the LTI 20-20 would be accurate to 0.1°, or approximately 1 ft at 200m, which is about half the width of the beam at that range. Such an example takes advantage of the lack of experience of the non-technical reader to raise artificial concerns about the accuracy of the instrument.

Subject heading – "Speed measurement from static object":

Clark makes a major point that false-positive results can result from "slip errors." Slip errors could be caused by a smooth sweeping our scanning motion of the beam – in one direction, in a straight line, at an angle - across the side of a vehicle or other relatively flat object. But the *likelihood* of an error, or the *size* of an error, depends strongly on the angle between the laser beam and the target surface. The angle between the laser beam and the surface can be described as "normal" (nearly perpendicular to the surface), "intermediate" (at some intermediate angle, for example roughly 45° to the surface), or "grazing" (a shallow angle nearly parallel to the surface).

Grazing angles: The slip error would be maximum at a grazing angle to the surface (aiming along the side of the vehicle nearly parallel to it), however, obtaining a false-positive reading would be practically impossible because this would require that the vehicle be extremely long. A sweeping motion at a very shallow angle would cause the beam to run off the vehicle before all of the data in the burst of laser pulses were acquired. Also, it would be unlikely to obtain a slip error at a grazing angle because of the extreme weakness of the reflected beam. Although the grazing angle measurement is the most likely type that might accidentally be encountered in a normal law traffic law enforcement application, it is the one with the weakest returned signal strength and thus the least likely one to produce a false-positive result.

Intermediate angles (~45°): Making a sweeping motion along a surface at about 45° could produce an error if there was sufficient return signal strength and the motion was uniform. However, even at 45° the return signal strength would be extremely weak and unlikely to produce enough good data points for a successful calculation. For that reason, Clark has targeted special surfaces with higher back-scattering efficiency for his demonstrations, to give the impression that slip errors are easy to reproduce. For example, Clark uses corrugated surfaces, which have numerous facets or parallel ridges. Parts of each ridge would be nearly normal to the laser beam direction (even though the entire corrugated surface may be oriented at 45°). A corrugated surface with square-shaped ridge profiles (as opposed to rounded, wavy ones) can act the in same way as a corner-cube retro-reflector in the horizontal plane, reflecting the incident beam back more efficiently in the same direction from which it, came regardless what that particular direction is. Finally, the overwhelming majority of vehicles have smooth surfaces, and it is also important to recall that intermediate (~45°) angles are essentially impossible to encounter when monitoring on-coming traffic.

Normal angles: The least frustrating way to induce a slip error would be to sweep the beam very rapidly over a surface at an angle nearly normal to the target surface, such as by aiming *across* the road at the side of a passing vehicle, rather than down the road in front of it. (Of course, any operator who attempts to measure the speed of a vehicle by aiming the speed gun *across* the road should not be surprised to obtain mediocre results). In any event, a slip error obtained by panning at nearly right angles to a surface would amount to only a few mph.

Item 47… Clark describes how Samantha Smith, a presenter for the BBC program “Inside Out”, obtained speed measurements in the range 50 to 100 miles an hour by observing a stationary wall. In her commentary, Ms. Smith goes on to say that false readings like these were easily obtained. To obtain these results she would have had to pan across the wall at approximately 20 degrees per second assuming a starting angle of approximately 45° to the wall, an assumption that seems reasonable based on the video footage. Such movements by an operator would be considered extreme, and would never be required under normal operating conditions. Furthermore, an operator knows the difference between a moving vehicle and a stationary wall, and can easily avoid any situation where a fence or building could contribute any competing signal. Of course, two competing signals would be rejected by the error-trapping software, and no calculation would be made.

If an operator where to make such an excessive movement under normal operating conditions the error trapping algorithm would capture it immediately, which would result in an error message and no displayed result.

Clark does not say whether to demonstrate a failure of the device Smith had been instructed in the specific technique that would produce this kind of result. If Smith was simply asked to take the LTI 20-20, aim it at a wall, and measure the speed of that wall, she would obtain a result of 0 mph over and over again. Someone would have to explain to her that a false positive result could be obtained by sweeping the beam smoothly across the wall at a particular angle - not perpendicular to the wall (which could only result in a speed close to zero) and not at a grazing angle to the wall (which would produce to too weak to return signal for a successful calculation). She would have to be positioned to aim at an angle more like 45° to the wall to obtain an error large enough to be of interest in a traffic law enforcement case.

Item 51… Clark explains that the laser beam is directed at the wall and the speed meter is then rotated so that the beam moves smoothly across the wall, as shown in Figures 31 and 32. Clark goes on to say that the speed meter has no knowledge that it has been rotated, the implication being that a slip error can be recorded despite the error trapping features being applied. But of course, the *operator* knows that the instrument has been rotated because the rotation has to be applied consciously in order to produce the false results. Considerable concentrated effort must be put into sweeping the beam smoothly to override the error trapping algorithm. Random, unintentional motions will not produce a sufficiently uniform data set to pass the error trapping test, and small unintentional motions will not produce a speed error large enough to change the measurement enough to influence the outcome in any significant way.

Item 55… At this point Clark states:

> “If the operator is attempting to track a vehicle he will be mimicking the vehicle's motion. But if during the measurement cycle, which lasts only 0.3 seconds, he moves off the target the speed measurement will be from whatever the beam is in striking, most likely the road surface or objects behind the target".

In normal operating mode, the laser beam would be at near grazing incidence to the road surface (assuming a 2 m high sighting position and 200 m target distance, the angle to the road surface is 89.5°). At near grazing incidence the laser beam would return an extremely weak signal from the road surface, which would be unlikely to produce any reading at all, or would result in an error message. In the extremely unlikely event that the signal returned from the road surface is strong enough, the speed calculated from the road as the operator follows the motion of the target vehicle will be the same speed as the speed of the moving vehicle itself.

Clark also says,

> "It should be noted that the action of pulling the trigger is likely to result in a slightly downward motion of the instrument, which will cause an increase in the apparent speed of the approaching vehicle".

What is the basis for Clark's assertions that a *slightly downward* motion is *likely* to result? Has Clark tested this assertion by measuring any possible subtle motions of these begun when the trigger is pulled, or if the same result if any is obtains by various different operators? How big is *slightly*, and why *downward* ? It is not obvious that the action of pulling the trigger is likely to result in a downward motion of the instrument. It might be just as likely to result in a slight *upward* motion of the instrument, or in no motion of the instrument at all.

Clark's assertion, that the act of pulling the trigger would move the speed gun in such a way that it could result in a false speed reading, is not supported by any measurements, data or factual information presented by him in his report.

Item 56… Clark makes another imprecise and unscientific statement:

> "The above problem will be exacerbated if even the slightest misalignment of the sighting mechanism is present (or crosshairs of the video if this means is being incorrectly used to target vehicles)".

The claim that the problem will be "exacerbated" falls into a familiar category of allegations in the report, statements that may be true, but which may not be of any significance because their actual affect would be negligible. For example, 91 mph is faster than 90 mph. The statement certainly is true, and an additional 1 mph would exacerbate the speeding violation, but certainly not enough to change the nature of the defendant's legal problems.

Subject heading – "Incorrect speed readings from moving targets":

Clark illustrates how a false speed measurement can be obtained by panning the laser beam along the side of a moving vehicle, a phenomenon which Clark attributes to slip. The problem is not that the beam has slipped. The problem here is that the beam is being aimed at the side of the vehicle. To measure speed or distance accurately, the beam should obviously be aimed at the *front* of the target vehicle, not at the side. Clark is implying that panning errors can occur accidentally, even for a trained operator. This is a gross exaggeration. The error trapping algorithm is optimized to reject data from unintentional motions. If the operator is instructed to aim at the license plate of the car, yet either inadvertently or intentionally pointed the beam at the side of the car, one should not have any expectation that a speed result will be successfully calculated. Such unintentional mishandling of the speed gun would inevitably result in an error message rather than false results presented on the display. Furthermore, the operator would certainly be aware of any large motions, and they would also be evident in the supplementary video record.

Item 60… Clark explains that in order to demonstrate this effect, two speed meters were used, one use as a reference (presumably aimed at the front of the car) and the other was *deliberately* slipped along the side of the target vehicle.

Item 69… Clark states, "The speed meter normally measures the distance to the closest target". This is not a correct statement. The instrument measures the distance to whatever the operator aims it at when the trigger is pulled. A correct statement would be, "The speed meter normally measures the distance to the target that is illuminated by the laser beam during the 0.3 second time interval during which the data is acquired.

Item 77… Clark claims that two trucks that appear in the video record to be "in approximately the same position" show a distance discrepancy between them of 58.4 m. Clark's assertion here is that because the two trucks *look* as if they are in the same place that they must be at the same distance, and therefore that the two different distance measurements must be due to an error made by the LTI 20-20 and an incorrect distance result produced by the device. This is a poor method of comparison. But Clark is serious. He seems to actually believe that if the two trucks *appear* in the same position along the line of sight. Then they must be at the same distance. Clark illustrates this with images 58, 59 and 60.

In truth, the target vehicles could be located at any distance along the let line of sight and still appear to be in "the same position" in the picture displayed on the video monitor. This is illustrated below in Figure 1.

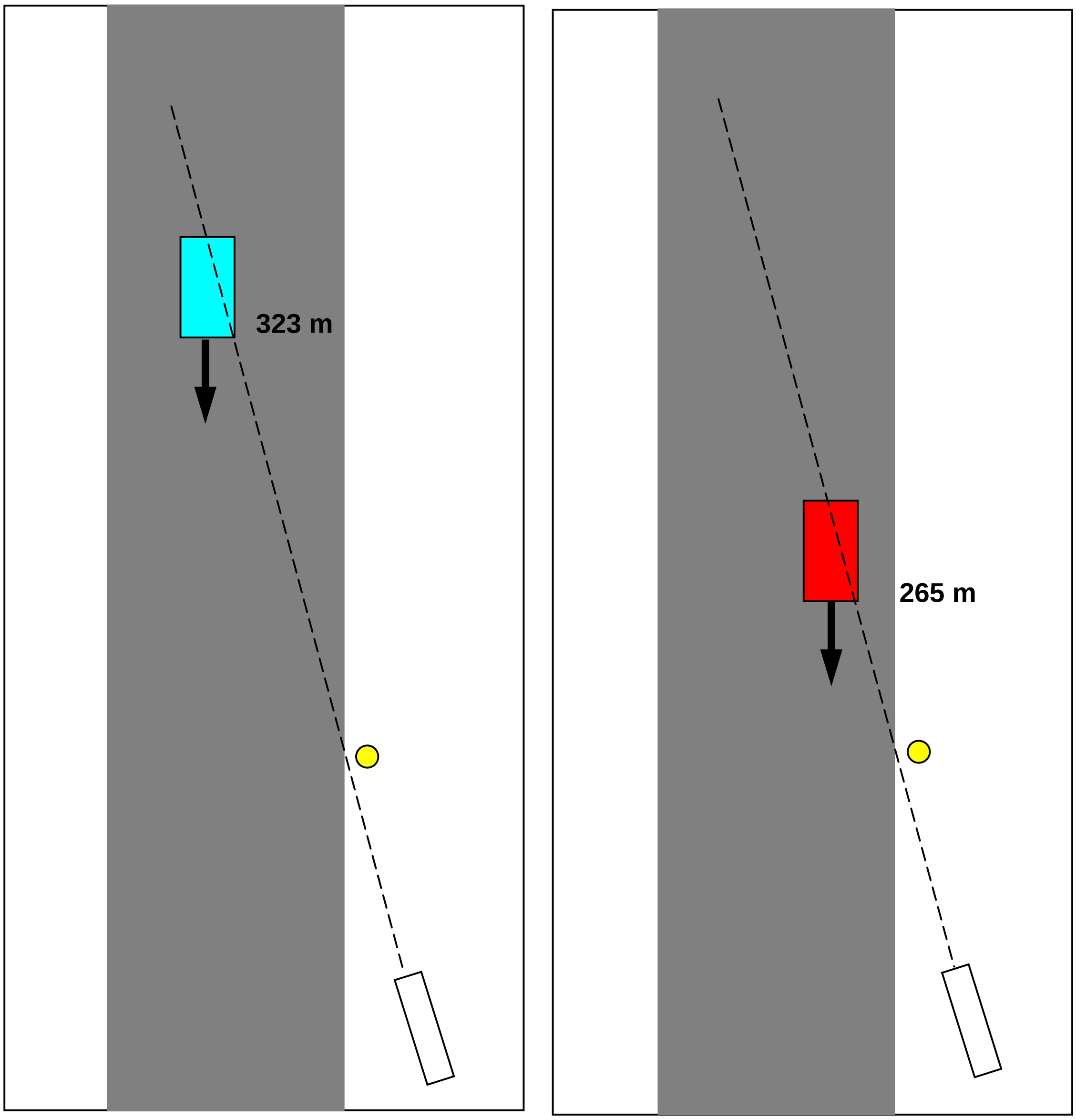

Figure 1: **Objects at different distances can appear to lie along the same line of sight. The traffic cone in Images 58-60 of Clark's report is indicated by the yellow circle.**

But there is another way to estimate the relative distances of these two trucks. If we knew that they were identical make and model we could compare their physical dimensions in the two images. Their relative sizes would be proportional to their distances from the camera.

The two trucks in images 58 and 59 are not the same make and model, but they happen to be of the same general type (straight, cab-over-engine, heavy freight trucks). It would be preferable to compare the widths of these trucks, because all large commercial trucks are usually as wide as legally allowed, and therefore the same width. Unfortunately, in image 58, the passenger side of the truck cab is obscured by a vehicle ahead of it, so we do not have that edge of the front of that truck for comparison. But the rest of the fronts of both trucks are clearly visible.

If we assume that trucks of the same general type have the same bumper-to-windshield dimension, then the relative sizes of the two measured that way would be proportional to their relative distances. (This is a obviously a questionable way to make such a comparison, but certainly no more questionable than Clark's assumption that the two trucks are at the same distance because they appear to be in the same place on the video monitor, which also assumes the two trucks were traveling in the same lane).

We can measure the distance between the lower edge of the bumper and the lower edge of the windshield on both trucks. In image 58 that dimension, measured directly off the page with an ordinary ruler, is 1-1/16 inches, corresponding to a distance measurement to that truck of 265 m displayed in the lower right corner of the screen. In image 59 that same dimension for the second truck is 7/8 inch, corresponding to a measured distance in this case of 323 m on the display. The difference between these two dimensions is 3/16 inch. If 1-1/16 inches corresponds to a distance of 323 m, then 3/16 inch (the difference between the two) correspondents to 57 m. Interestingly, this distance is essentially the same as the 58.4 m distance discrepancy that Clark ascribes to a failure of the LTI 20-20. So, comparison of the dimensions of the two trucks suggests that they were photographed at two different distances, as measured correctly by the LTI 20-20.

Our approach uses a much more realistic assumption – that two trucks of the same type are nearly the same size. We then compare their dimensions in the images. The difference in their apparent distances that that we calculate from their sizes is the same as the measurements made by the LTI 20-20, and we conclude that the instrument performed correctly. Clark assumed that that the trucks must be at the same distance because the two images overlapped in Image 60, and concluded that the LTI 20-20 had malfunctioned. Our conclusion is clearly the more plausible of the two. It could be argued that the answer we obtained was purely a coincidence but, if so, it certainly is an amusing one.

Subject heading – "*BBC programs*":

Clark gives numerous examples of what he claims are inaccurate or undesirable effects that he was able to demonstrate for several popular TV programs. These demonstrations were not scientific tests, but were simply conducted for the purposes of informing and entertaining the audience.

Item 86… Clark describes how the BBC reported portrays the problem of holding the laser beam steady on the target. He quotes the program's reporter as saying that a movement of "about the thickness of a human hair" would cause the laser beam to slip from the front of the vehicle to the side. This leaves the impression that aiming the laser gun is a very delicate procedure, and that even the slightest motion would corrupt the measurement. The term "human hair" is certainly a vague way to quantify any effect involving angles or displacements. How to does the term human hair pertain to rotation, or to translation (lateral motion without rotation)? Translation of the laser gun by the width of a human hair, or even 1 foot, would have no detectable affect on the measurement or contribute to the so-called "slip" phenomenon. How does the thickness of a human hair describe angles? Would it be the distance that the front of the lens this would have to move? If so, move relative to what, the handle of the gun, the eyepiece of the sighting scope, the shoulder of the operator? Of course, this is only the personal opinion of a BBC reporter, and not an analysis by an engineer or an instrument technician. If so, then why would Clark include such an imprecise characterization in a technical report that was intended to support his expert testimony in court.

If the device is tested under the conditions in which it should be used and calibrated according to this simple procedures is recommended by the manufacturer, and if the device performance consistently with high accuracy and repeatability with few rejected measurements, then it is deemed to be a robust and reliable measuring instrument.

Item 87… Clark takes exception to the fact that "type approval of the LTi 2020 was granted on the basis of a translation of the German report on speed measurements conducted by a German test house". The fact that the instrument was evaluated by a German test house should only increase the confidence of the findings of the report. The fact that the German report was translated into English would seem to be irrelevant. We can presume that the UK government would receive a competent translation from a German technical organization.

Item 88… Clark states that, “Had a speed error been recorded during type approval testing for the home office, the device would have failed type approval.” Clark's statement is more theatrical than scientific. His logic seems to be: ‘We made the gun produce a speed error… a speed error is grounds for the failure of type approval… therefore evidence obtained by the gun should be disqualified.’ The logical failure here is that Clark's demonstration that produced a speed error is not the same as the testing procedure that is performed to qualify the instrument for type approval.

Clark deliberately misused, de-calibrated, misaligned and abused the instrument and took data over, and over, and over again, until he was able to generate a failure. The LTI 20-20 received type approval because it did *not* produce speed errors during the testing that is required by the Home Office. If Clark was to put the same effort into using the instrument according to the manufacturer's instructions, into calibrating and checking it in accordance with the manufacturer's guidelines, and under conditions typical of traffic law enforcement applications, he would have no false-positive results to show for all of his efforts.

Subject heading – “*Tests Conducted with Daily Mail*”:

Clark states that the Daily Mail newspaper published an article on the 15th of October 2005, and he remarks that "the newspaper's editor considered it to be of sufficient merit to make front page headlines". It is much more likely that the Daily Mail featured the report for its entertainment value, or to satisfy the curiosity of their readers.

Subject heading – “*Device Test*”:

Item 107... Clark refers to image 79, showing the view through the scope that the operator sees the speed gun was mounted on a tripod and two vehicles located 375 m away were targeted. He states that it was impossible to tell which vehicle is being targeted, and that “just lightly tapping the device” cause a red dot to “move all over the place.” The terms “lightly tapping” and “move all over the place” are completely subjective. The real question is: Would motion that caused the red dot to “move all over the place” be able to induce a false-positive speed reading?

In item 111… In his summary, Clark states:

> “Laser-based speed meters can provide speed measurement errors with several mechanisms that include: beam spread, misalignment, erroneous speed reading

from static surface e.g., a wall or road, incorrect reading from targeted vehicle due to slip effect, incorrect speed reading via reflection."

Perhaps these measurement errors can be forced under artificial or carefully staged circumstances, but certainly that does not mean that they actually can or do occur in the normal application of the device. Clark does not specify or estimate the likelihood that any of these errors will occur under normal use. For example, is Clark alleging that incorrect results are obtained once in 10 measurements? Once in 100? Once in 1000? Maybe he means only once in a million measurements? Without quantifying his claims, Clark leaves the reader to trust that he would not mention anything that was not a serious, frequent problem. Thus he resorts to persuading the reader with an emotional, rather than rational, argument.

Summary:

By deliberately misaligning and de-calibrating the LTI 20-20 instrument, and then intentionally operating it in a manner that violates the few simple rules and procedures that should be observed to obtain reliable results, Clark obscures the true reliability and robustness of the instrument. Any responsible user of the instrument, who can simply squeeze the trigger of the speed gun without making any abrupt or deliberate sweeping motions, will find that it produces accurate results (with an occasional error message and no result displayed) essentially all of the time.