SPIDERS IN THE CROSSHAIRS: COBWEBS, INSTRUMENTS MAKERS, AND THE SEARCH FOR THE PERFECT LINE

Steven Turner

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For over a hundred years, throughout the last century and well into the current one, the most precise determinations of time, size and geographic position have depended on measurements made with spider webs. While the use of spider web in optical instruments is relatively well known, its importance to the dramatic increase in the precision and utility of these tools is not. At a time when such natural materials as wood and ivory were being discontinued, the use of spider web actually increased. As optical instruments evolved, manufacturers became increasingly sophisticated in their selection of web and in their techniques for working it. The 20th century saw the development of independent suppliers, collecting and selling specified types of web to instrument makers. Many traditional applications of web have, in recent years, been eliminated by new technologies, but spider "silk" continues to be an important natural resource.

The use of cross-hairs and the development of micrometers was made possible by the introduction of telescopes with an interior focus. Astronomers experimented with silk, human hair, brass plates, and silver wires, but found that these materials obscured the stars they wanted to observe, and that they broke or sagged with vibration or changes in temperature and humidity. William Herschel complained of the filar micrometer he used in the 1780s to compile star catalogues: "I have attempted in vain to find hairs sufficiently thin to extend them across the centres of the stars so that their thickness might be neglected. The single threads of the silk-worm, with such lenses as I use, are so much magnified that their diameter is more than that of many of the stars."(1) Herschel was apparently unaware that an Englishman named William Gascoigne had been inspired, by seeing a spider web in his telescope tube, to make the first astronomical micrometer around 1639, and that an Italian named Felice Fontana had published an account of using a spider web in a leveling instrument in 1755.(2)

David Rittenhouse, independently, discovered the advantage of spider-lines for cross-hairs. In a letter read to the American Philosophical Society in 1785 he reported: "I have lately with no small difficulty placed the thread of a spider in some of my instruments, it has a beautiful effect, it is not one tenth of the size of the thread of the silkworm, and is rounder and more evenly of a thickness. I have hitherto found no inconvenience from the use of it, and believe it will be lasting, it being now more than four months since I first put it in my transit telescope, and it continues full extended, and free from knots and particles of dust."(3) Subsequent investigators found that besides being thin and uniform, spider web is elastic, and stronger by weight than steel. While it tends to sag when exposed to high humidity for long periods, it usually recovers its tautness when dry. It is also more uniform than other materials.

Andrew Ellicott followed up on Rittenhouse's lead, writing to Thomas Jefferson in 1802: "I have with great difficulty, and patience, placed a reticule of spider's web (the first ever executed), in the focus of this instrument!"(4) Edward Troughton seems to have been the first Englishman to make use of Rittenhouse's discovery, and his example inspired other instrument makers to use spider lines in astronomical and surveying instruments.(5) Spider line micrometers, used with large aperture objectives on stable equatorial telescopes and/or transit instruments, brought a new level of precision to astronomical observations. In 1824, John Herschel and Sir Edwin South, using a Troughton micrometer on their 5 ft. focus equatorial telescope, measured position angles to the unheard of accuracy of 1" of arc.(6)

Astronomers were not alone in their appreciation of spider- lines. An 1856 text noted that a well constructed "cobweb" micrometer was probably the "most perfect instrument that the Microscopist can employ."(7) Used with the high power lenses of that time it was capable of measuring objects to within 1/100,000 of an inch.(8) But precision had a price. Because of the difficulty of designing and constructing the delicate mechanisms which moved the lines, these micrometers were notoriously expensive.

Machinists used paired microscopes, each equipped with spiderline micrometer eyepieces, to ensure that identical metal bars, called Line Standards, were actually identical.(9)

Despite its many advantages, web faced competition from other materials. Fine platinum wire was introduced in 1813, and "platina hairs" or "platino-iridium wires" remained available through out the century.(10) The finest platinum wires with diameters of less than .001 inch— approached the coarsest spider lines. When subjected to repeated cycles of heat and cold, they tended to become brittle and work loose from their fittings. Moreover, it was difficult to remove dust and oxidation from the wires. Spider lines did not oxidize, and could usually be cleaned by gently blowing on them. There are numerous instruments with intact spider-lines in the collections of the National Museum of American History, many over 100 years old. They resemble very fine pencil lines drawn with a ruler. Platinum wires are much thicker and darker, often dirty, and often not straight.

Almost all instrument makers offered micrometer eyepieces with moveable glass slips onto which ruled lines had been scratched (or etched). While not as precise as "cobweb" micrometers, they were still very accurate, and their price made them attractive. In 1896, a fully adjustable Bausch & Lomb filar micrometer sold for $45, while a micrometer eyepiece with a moveable glass scale cost only $12.(11) Similar glass scales were used for stadia lines for surveyors. Although these scratched lines were permanent, the glass absorbed some of the light. Moreover, the glass tended to fog when the temperature fell, sometimes needing to be removed, cleaned, and replaced several times an hour.(12) Improvements in the method of making the lines, and the development of sealed instruments and improved lens coatings, made diaphragms with glass plates increasingly attractive. There remained, however, a "considerable difference of opinion amongst surveyors as to the best form of diaphragm, some preferring webs whilst others consider that those ruled in glass are superior."(13)

For the U. S. Coast and Geodetic Survey, whose need for precision bordered on the obsessive, the use of web was never seriously questioned. Despite the fact that the Survey's shop occasionally produced ruled-glass diaphragms for commercial instrument makers,(14) the Survey used web in all their geodetic instruments. While lines drawn on glass could be as fine as .00015 inch thick (roughly the diameter of a typical strand of web), a spider line could be split to produce a thread measuring a mere .000075 inch.(15)

Instrument makers took care to obtain the best web for the job at hand. Kolesch & Co., for instance, advertised that "The Cross and Stadia Hairs in our telescopes are of the best web, uniform in thickness, and are reliable under all atmospheric condition."(16) Buff & Buff noted that the "proper thickness of spider web...is governed by the magnifying power of the respective telescope and the diameter of web that fulfills the proper requirements."(17)

Most English makers preferred silk from the spider marked by a cross on its back and "found in English gardens about decaying wood." Troughton preferred the webs of young spiders, specifically, the "lines formed by the insect to capture and secure his web," noting correctly that these lines were stronger and more elastic than the others.(18)

The English astronomer George Airy went a step further, using ultra-fine cocoon silk, what he called "silk from the ball," for the filar micrometer of the 10 foot transit instrument at Cambridge University.(19) Egg sacs were also used by surveyors who needed to repair their instruments in the field. These sacs had to be empty because, if the eggs hatched before the sac was used, the young spiders would destroy it in their efforts to get out. For the more fastidious, some manufacturers sold "Wire fork carrying spider's web for field repairs."(20) .

C. L. Berger & Sons of Boston supplied their surveying instruments with only those fibers found next to the eggs, "on account of their fineness and darker color." This company preferred web drawn "from the cocoons of the small black wood-spider" which was native to the area around their plant, but in 1900 they switched to the cocoons of a species of spider native to Michigan supplied to them by Prof. J. B. Davis of the University of Michigan.(21)

The basic techniques for harvesting, processing, and installing spider lines changed very little over time. Ideally encountered when it had just begun spinning a new web, the spider was placed on a bent piece of thin brass wire, called a "fork." As the spider tried to escape by spinning a line to the ground, the fork was turned and the web was reeled in. About a dozen forks could be obtained from a single spider before it was exhausted.(22) The web was subsequently secured to the fork with varnish and then stored in an air-tight wooden box.

Before being used, the web was cleaned (by soaking in clear water) and stretched. Following Troughton's lead, makers would cut notches in the eyepiece diaphragm and then, under tension, attach the webs one end at a time, with varnish or shellac.(23) By the early 20th century, makers had developed special machines for each step of the process. Buff & Buff, for instance, had a "Diaphragm Ruling Apparatus" which could cut the tiny grooves which held the web to a precision of 1/50,000 inch.(24) This allowed the construction of diaphragms where horizontal and vertical lines were so close together that, even under high magnification, they remained in perfect focus. "One of the most essential points in a good micrometer is that all the webs shall be so nearly in the same plane as to be well in focus together under the highest powers used, and at the same time absolutely free from 'fiddling'" (i.e., touching one another).(25)

The first known full-time web collector was Mary Pfeiffer, who went to work at age 14 as for Keuffel & Esser in Hoboken, New Jersey in 1889, and who was still working in 1941. Using 200 spiders of only two species—Epeira Diademata (a common garden spider) and Zilla Atrica (which she obtained from the pig sties of Secaucus)—Pfeiffer collected over 2,000 feet of web each year.(26)

Clearly possessed of considerable patience, Pfeiffer let her spiders move freely and produce web at their own pace. She would release a spider into her small office, and then follow it about. Once the spider began to spin, she would attach the end of the web to a small wooden frame, and slowly reel it in—gathering up to 60 feet a day. Her reels consisted of two wooden dowels held four inches apart by two lengths of wood. When full, each reel held 23 feet of web. Cleated into specially constructed wooden boxes, they could be shipped anywhere in the country.

John G. Albright, an associate professor of physics at the Case School of Applied Science, started a "spider ranch" in the late 1930's, collecting mature female Golden Garden spiders (Miranda Aurentia) in late summer from the branches of blackberry bushes which grew wild on his Ohio farm.(27) Albright "milked" his spiders by allowing them to crawl across a large piece of canvas until a thread appeared. He then wound it onto 3" square wooden "reels," each of which held 100 feet of web. Albright also installed web. When split web was required, he used "a wire fork shaped like a hairpin" to lift a single strand from one of his reels. By inserting a fine-pointed dissecting needle into the spider line, he could separate the four strands which composed it to produce a line that was nearly invisible.

Dr. Albright's business was eventually assumed by his nephew, who packaged his web in boxes with printed labels which read:

SPIDER SILK
For Optical Instruments
Grown and Produced
by
Albert A. Albright

Albert supplied a pamphlet which gave a brief history of the uses of web, as well as instructions for installing it, which ended: "Patience and care are essential, especially when two or more cross-lines are mounted on the same reticle, but if one does not hurry or become impatient, he will be surprised at the ease with which this difficult task can be performed."

Nan Songer (later Songer Hook), who began working with spiders in 1939, took the art of web-collecting to new levels of precision. (28) In the sun-room of her home in California she tested the web of over 50 species of spiders, recording size, strength and elasticity. With the encouragement of the National Bureau of Standards and several optical instrument manufacturers, she developed the ability to provide web to specifications. Her 1942 mail-order sheets listed web ranging from "extra-fine" (1/50,000 inch) to "extra-heavy" (1/5,000 inch). The price for 100 feet of spider silk was $10; split silk cost $15. For extremely sensitive instruments, Songer offered the silk of week-old baby spiders. Measuring 1/500,000 inch, it was all but invisible.

Although she extracted web from only three species (Latrodectus mactans, the Black Widow; Argiope trifasciata, the Banded Garden Spider; and Aranea gemmoides, a large orb weaver), Songer was able to produce a wide variety of silk by collecting it from spiders of varying ages. Disdaining the "puny," males, she found that a given species of female spider, of a certain age and size, invariably produced the same size and type of web.

To provide web on a timely basis, Songer kept an inventory of as many as 10,000 live spiders. During the winter, she would force baby spiders to grow by removing them from their egg sacs and placing them in warm cages. Songer used a soft camel-hair brush to "tickle" the spinnerets until a drag-line emerged. The spiders grew accustomed to the procedure. In her words: "Some of the regular producers get as docile as old milk cows, particularly the Black Widows." Songer found that she could silk a spider as many as 25 times, and that starving the spider for several days before silking produced web with fewer impurities.

New technologies, introduced in the last three decades, have supplanted many of the uses of spider line. Atomic clocks, satellites, and electron microscopes now provide the ultimate in precision. Web, however, is still used for many traditional optical instruments, as well as in the sights for sport rifles and military weapons, and in the calibration of instrument landing systems in aircraft. The North American Survey Supply Co. in Philadelphia uses web in new instruments and for instrument repair. They also sell web to other companies. In 1984 web on a fork was selling for is $2 a foot.(29)

Some scientists are attempting to produce web in their laboratories. Genetic engineers at the University of Wyoming have isolated the web-making genes of spiders and spliced them into bacteria. To collect silk for their investigations, they anesthetize their spiders, tape their legs down, "grab the fiber with tweezers, attach it to a spool on a variable_speed drill, and spin it out."(30) What would Rittenhouse or Troughton think?

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