INCREASING RESEARCH FLEXIBILITY WITH ENDOWMENT FUNDS

(In Defense of Research by Serendipity)

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The purpose of this paper is to consider how the freedom associated with spending endowment money as opposed to grant money for research may allow a professor to explore high-risk research without the possible embarrassment of a public failure. At the University of Kansas (KU), the expenditure of Distinguished Professor endowment funds requires only fiscal, not scientific, accountability, which is a great advantage to those fortunate enough to have access to such funds. Like an old-time country doctor, one can bury one's mistakes.

The ideas presented here are in part gleaned from the book "Shocks and Rocks" by National Academy of Sciences member Jack Oliver, one of the leaders in the development of the theory of plate tectonics in modern geology. From grammar school onward, we are taught about THE scientific method, as though it were the only method with any merit. This cherished method is commonly known as "hypothesis testing."

At least two problems with this classical form of the scientific method come to mind. First, investigators tend to get married to a hypothesis. That is, their egos become involved, and they are afraid to be wrong. As a result, they may not be willing to admit to a failed experiment, or they are reluctant to recognize that they were on the wrong side of the hypothesis at the outset, or they may carry the research well beyond the point of diminishing returns.

The second problem is that the hypothesis-testing method is so deeply ingrained in the competitive scientific-funding system in the U. S. that obtaining funding from such sources as the National Science Foundation (NSF) is very difficult unless a proposal contains a testable hypothesis. For example, Dr. Wes Jackson, a MacArthur Fellow from The Land Institute (TLI) in Salina, Kansas, recently proposed to the NSF a study to use TLI's unique facilities to study the long-term effects of different types of vegetative cover on soils. The proposed research was to be limited to a single soil type located in adjacent locations, and it included virgin prairie, Conservation Reserve Program grass, and active cropland. Besides examining the micro- and macrobiota, the chemistry, structure, and texture of the soil were to be investigated as well.

Dr. Jackson's proposal received reviews that were all "very good" or "excellent," but the NSF panel rejected his plan because it lacked a distinct hypothesis. The reviewers otherwise were impressed with the proposal, but because it lacked an explicit, testable hypothesis, the proposal was not considered fundable. This kind of experience with competitive funding sources is all too common.

Dr. Oliver points out in his book that, in addition to hypothesis testing, he has used two other scientific methods that have little to do with testing a hypothesis. He calls these two methods "Science by Synthesis" and "Science by Serendipity." As an example of the *synthesis* method, he cites the famous "Seismology and the New Global Tectonics" paper from 1967, of which he was a co-author. This paper is seen by many as the rational beginning of modern plate-tectonic theory. As an example of *serendipity* he cites the 1967 paper by Oliver and Sykes that reported the chance discovery, by means of earthquake seismic methods, of the sinking into the earth's mantle of crustal slabs or *plates*, which was one of the keys to unlocking the ways in which the dynamic earth works. To quote Jack Oliver:

> The message here for young scientists is, of course, that no one style of doing science is obviously superior or should be exclusive, and furthermore that science would be less effective if forced into any one such mode. I hope this point is made sufficiently clear so that all peer reviewers will note it! I shudder to think of how backward science might be if all research of the past had been confined, as some peer reviewers have erroneously recommended, to only projects for which the hypothesis is "clearly and explicitly" stated or the problem "sharply defined."

Although both the hypothesis-testing and the synthesis methods are considered appropriate bases for the expenditure of endowed funds, this paper provides an example of the use of endowed funds from the Dean A. McGee distinguished professorship at KU in support of research by serendipity.

Dictionaries define serendipity as "the faculty of making providential discoveries by accident" and as "a gift for finding valuable or agreeable things not sought for." Such a gift favors those who are observant and well prepared—as well as lucky. To describe my own experience with serendipitous discoveries made possible by McGee Professorship funds, I would like first to discuss the background of my research.

The subject of my research is imaging the shallow underground using seismic reflections (sound echoes). This type of imaging has much in common with ultrasound imaging as used by the medical profession and with deeper types of imaging as used by oil companies as they search for geologic structures capable of holding petroleum reserves. In both cases, the principal differences are those of spatial scale. Physicians often work on a scale of millimeters, dealing with structures found in the human body. Oil companies use a scale of hundreds of meters as they deal with structures in the earth. My colleagues and I, however, analyze features on the scale of one meter.

Constructing images of the shallow underground is desirable for many engineering, environmental, and geological reasons, such as searching for underground voids that might cause the collapse of structures and roads. Seismic imaging requires a source of underground sound waves, and that is where my first example of serendipity arises. Physicians use a small electronic transducer that produces sound in the range approaching one megahertz. Oil companies have long used dynamite as an underground sound source with frequencies in the sub-audible to low-audible range, i. e., about 10 Hz to 50 Hz. My work requires frequencies from about 100 Hz to about 1000 Hz. Musical middle C, for example, has a fundamental frequency of 264 Hz. For many years my group has been using rifles as sound sources, including a 50-caliber machine gun fired into shallow holes in the ground. Despite decades of effort by our group and many others, no one had ever extracted sound waves successfully from the ground at frequencies above 600 Hz.

With $24 worth of McGee Professorship endowment money, I went to a local auto-parts store and purchased a 100-foot-long sparkplug wire. I could tell that my graduate students did not have their hearts in the experiment, and that they were just going through the motions to placate the old man who pays their salaries. We disconnected one sparkplug wire from the engine of my truck and connected the 100-foot wire in its place. Then we connected the other end to a sparkplug about 90 feet away that had been pressed into a dampened hole in the ground one centimeter in diameter by about two centimeters deep. We arranged our sound sensors (which are low-frequency microphones called *geophones*), started the truck, and began listening with our seismograph. In an experiment that required less than two hours to perform, we were able to extract sound waves from the ground at frequencies up to about 1400 Hz. It took us about half a day to analyze the data and another day to prepare graphics and a manuscript for publication. The paper was published in the March-April 1999 issue of *Geophysics*, the world's leading journal in exploration geophysics. Incidentally, the $300 page-charge fee exceeded all of our other research costs for this experiment.

Although a new shallow seismic wave source resulted from the sparkplug experiment, getting the sound waves into the ground is only half the problem in near-surface imaging. The other half is sensing the sound with geophones attached to the ground. Oil companies typically position geophones on the ground at intervals of the order of tens of meters. For our work, we commonly use geophone intervals as small as five centimeters, which makes such surveys very expensive because of the amount of human labor required. Prior to 1997, we had never experimented with geophone intervals smaller than 25 centimeters, but our KU research group set the world record in 1986 for the shallowest seismic reflection at 2.6 meters using that geophone interval. This record stood until 1996, when a graduate student at Stanford recorded reflections at a depth of 2.0 meters.

We accepted the loss of the record to Stanford as a challenge, so late in 1997 we began experiments with geophone intervals at 10 centimeters. We regained the record by acquiring reflections at a depth of 1.5 meters. In early 1998 we decreased our geophone interval to five centimeters and improved the record to a depth of 0.6 meters, where it now stands. As a slightly inebriated Australian professor told me upon viewing the data at a conference reception a little over a year ago, “Thish could schtart a whole new indushtry!” In his slightly impaired state, he did not realize the tremendous cost of doing such a survey.

The desire to radically decrease the cost of such surveys is where serendipity enters the picture again. Having established that this type of shallow imaging was possible and heartily wanting to trigger a whole new industry, we needed to find a fast, cheap, and effective way to plant lots of closely spaced geophones. I wanted to know the severity of the problem that we faced, and it seemed to me that the best way to initiate that was to bolt a bunch of geophones to a rigid medium to find out how the seismic signal was affected.

All of the mathematical analysis of geophones dating back to the early 1940s suggested that it would be impossible to extract usable signal from multiple geophones attached to the same rigid medium. But sometimes one experiment is worth a lot of equations and computer models. With about $7 worth of McGee endowment money, I bought some nuts and bolts and went to work with the arc welder in my basement. I bolted the geophones to a scrap of board, and the next time my graduate seismology class was out in the field for an experiment, we planted the board-mounted geophones in the middle of a line of geophones that had been planted in the usual way. Much to our surprise, we found that it *is* possible to bolt many geophones to a single rigid medium and still collect good seismic data. These results were published in a paper entitled “Geophones on a Board” in the May–June 1999 issue of *Geophysics.*

Extending these results with about $200 worth of McGee endowment money, we purchased some long pieces of channel iron from a steel supplier in Lawrence and bolted 72 geophones to the channel iron. We hauled everything to my farm in Palco, Kansas, and welded the channel iron, with geophones attached, to the underside of the frame of an 11-meter-wide tillage implement. Using the hydraulic power from a large farm tractor, we were able to plant 72 geophones in about two seconds in our test line, whereas planting the comparison line, where we used normal human-planted geophones, required 15 minutes of labor from each of three people. Upon recording signals on both lines, it became obvious that the key seismic information had not been affected by the presence of the rigid steel medium to which the geophones were bolted. We have shown that it is possible to plant large numbers of geophones quickly and cheaply, while preserving the salient features of the resulting seismic data. These results were published in the April 1999 issue of *Geophysical Research Letters*, a leading refereed journal of current research topics.

In summary, none of the results described here could have been foreseen or described in the form of a testable hypothesis, which seems to be necessary for submission to a funding agency such as NSF. The total outlay for the research summarized in these three refereed papers, including student salaries, was less than $10,000. The upshot is that having the freedom to spend a relatively small amount of money without having to write a proposal or, in the case of failure, a final report, has allowed me to think freely, move quickly, and perform serendipitous experiments that I would have been embarrassed to propose to colleagues outside of my research group.

My point is that the Federal funding system, at least in its competitive venues, is strongly biased toward proposals in which hypothesis testing is the method of choice. Knowing that, how can university administrators assist their faculties and staffs in obtaining Federal funding? My suggestion is that providing readily accessible seed money with no scientific reporting strings attached such as endowment funds to individual researchers would be a good policy. The freedom to explore high-risk research will pay off handsomely in some cases, but it will also lead down many blind alleys in which the money may seem to have been wasted. Consequently, even top-notch, experienced scientists cannot be expected to produce large amounts of funding from each parcel of seed money. Nevertheless, across the broad spectrum represented by a university, many successes may be expected over time.

References

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