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NASA, SPIDERS AND I

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In the summer of 1988, a group of science teachers asked me to talk about spiders. When I inquired about their special interest, they all mentioned the experiment with spiders in space. Suddenly I realized that it was about 20 years since the first plans for that experiment had been worked out. Apart from the results, the why and how of that event seemed to make it worthwhile to reminisce about it. As time goes by, there remains only the report on results by Witt et al. in the Journal of Arachnology 4: 115-124, 1977, which does not try to deal with the frustrations of my dealings with the National Aeronautics and Space Administration (NASA). Here is a summary of the events which surrounded the "Spider Web Building in Outer Space". For the quantitative results of measurements and observations one has to consult the earlier "Evaluation of Records from the Skylab Experiment" in the Journal of Arachnology.

NASA began around 1968 to plan for a laboratory outside the Earth's atmosphere, where experiments could be carried out which would clarify the effects of space on various earthly processes. As I perceived it, one of the main goals was an analysis of the consequences of weightlessness on biological systems. Nobody had experience which would predict how we would stand up to long exposure to weightlessness, and to whatever other forces and radiation which existed outside the Earth's atmosphere. Scientists, laboratories and universities received a call soliciting proposals for experiments to be carried out in a future space laboratory. [One of the conditions for the acceptance of the proposal was that the experiment should occupy little space, that it needed no human operator, and that the results could be transmitted to Earth.]

At the time I had nearly 20 years' experience in the analysis of spider web geometry; I had tried to learn to read web patterns, measuring the geometry to learn the inner workings of their builders. To clarify questions about gravity, I had actually pasted lead weights on the back of cross spiders (*Araneus diadematus* Cl.). The webs built with the weights were compared to webs built by the same animals before and after the weights. The main finding was that weight-webs were built with a shorter thread than those without the extra weight. When the web material was measured through nitrogen analysis of the web protein, my friend David Peakall could establish that it was about equal for control and weight webs.

We concluded that the heavier spider, which extruded a thicker silk strand, was now able to let itself down on its thread without risking rupture. One can only speculate in what way the spider became aware of its own body weight and acted accordingly. The experiment showed that spiders were sensitive to weight changes and could therefore become interesting candidates for experiments in the space laboratory. All our webs were longer than wide, of oval shape. How would that change when there was no up or down? The webs could be photographed in the space laboratory, and the pictures and animals could be brought back to Earth for measurement and observation.

The proposal to enter spiders into the Biosatellite Program was entitled: "Effects of weightlessness on web-building behavior of spiders". NASA accepted the proposal, and they sent technical personnel to Raleigh to learn how to handle spiders. During the following months cages were developed which would fit into the space laboratory, and which would permit spiders to build full-sized webs. The spiders could travel with the astronauts and could be released by them on arrival. In preliminary investigations spiders were exposed to vibrations and to a special oxygen-nitrogen atmosphere, and their webs were monitored before and afterwards. These webs were to serve as controls which established that the launch alone would not affect web-building and that the web changes observed in the space laboratory were due only to the peculiar conditions there.

The preliminary efforts were followed by a chain of events which taught me more about the difficulties of dealing with a large government organization than about spiders. In the end the Biosatellite Program was never flown. The personnel which had worked on the preparations and become familiar with the handling of spiders left NASA. My continued inquiries remained unanswered.

About three years later, in 1972, I learned from the newspaper that the people who worked on Skylab II had adopted a proposal from a high school student, Judith Miles, from Lexington, Mass. to send a spider into space and watch its web construction there. The neglected NASA had tried to gain popularity through involving high school students in their planning. When they had received the spider proposal from Lexington, they found it convenient to use the results of previous efforts with spiders, but under no circumstances wanted it attributed to an adult scientist. The girl had generated her plan after reading an article in the National Geographic Magazine of 1971, in which there were pictures and a discussion of my methods of web measurement.

There were efforts underway now to learn more about measuring webs without giving credit to anybody but NASA and Judith Miles. I was more interested in the outcome of the experiment than in getting credit, but I wanted to keep my fingers in to see the webs as early as possible and get a chance to measure them. I accepted a request from NASA to train Judith Miles in the Raleigh laboratory to handle spiders. She appeared with her mother, who turned out to be the driving force, asking all the questions and observing spiders. They spent a week in Raleigh, during which time I learned about the embarrassment caused by a pushy parent. I believe that I succeeded only in exchanging a few short asentences with Judith. After that I became completely dissociated from the project, while the Miles family dealt with NASA and the preparation of the spider experiment in space. When photographs came back from Skylab, a fact which I learned from newspapers, I was not granted permission to look at them. I was informed that for two years Judith would have exclusive rights to the pictures.

But there was an opportunity to learn about the behavior of spiders long before the end of the two years. I had written to Walter Cronkite of CBS TV news whether it would be possible to direct the camera in Skylab at the spiders. They showed daily pictures of astronauts brushing their teeth or eating; I suggested that the cameras could do more important work. It was common knowledge that most of the photographic equipment had suffered damage when the laboratory had been exposed for some time to high temperatures, due to a defect in its insulation. We might never see web photographs, but could we at least see samples of the animals' behavior? A telephone call informed me that spider pictures would appear on the evening news at the end of August 1973. Our local station taped the scene, and I obtained a chance to look many times at the strange behavior of the animals in space.

Seeing the spiders in space was for me very exciting and worth all the years of waiting. Two animals had made it all the way into Skylab; and at the time the pictures were taken, one had been several weeks in the frame, the other was just released. The first animal moved quickly around the cage, using the existing silk for support. The new animal floated slowly through space. When it touched the frame, it bounced back and floated in the opposite direction. Its legs were extended and hardly moved. The silk, which one could observe coming from the spinnerets at the end of the abdomen, wafted in wide waves through the air. It would have been stretched tight by the spider's weight on Earth. The spider obviously missed its usual clues, on which it would have descended, holding on to the tight thread. It could no longer handle the situation in an appropriate way and presumably waited for what would happen next. I saw something which no human eye had ever observed before: one spider's ability to cope with weightlessness after a few weeks of trial and error, and the new animal's helplessness. Thanks to the kindness of the people at the local TV station, I looked at this 12 times over. I quote from old notes:"... the spider newly put in tumbled, its movements were head-over-heels, as never seen before; the animal rotated in space while moving in one direction, bounced off the frame and moved back. In contrast, the first spider ran very competently along the strands to escape from the astronauts." It was concluded that there is a transition time during which spiders gradually acquire the skill to move "competently" under weightless conditions.

Nearly two years later, in April 1975, I received without any explanation a large package from NASA. It contained flight protocols, photographs and spider carcasses. The protocol permitted us to fix the dates at which things happened. The photographs, though very poor in contrast and too small to see the outline of the web, permitted measurements. We compared those measurements to web measurements from webs of the same species and age group of spiders in our laboratory. As far as I know Judith Miles (or her mother) had never measured the photographs.

There were only 5 photographs of control webs built by the two space spiders before the launch. This meant that only severe changes could be identified. Luckily, some of the changes exceeded anything that had ever been observed on Earth. In my opinion the most significant result was the observation that large geometric orbs had been built at all in space. The spiders had managed to cope with conditions which neither they nor any of their ancestors had met before, and they had constructed a large, functional trap for food in the absence of cues they normally receive through gravity. Adaptation had occurred in a few days.

When the spiders appeared on the TV film on August 23, they had been away from Earth since July 28, more than four weeks. They had had different experiences: one had been out of the transport vial and in the cage since August 4, the other just came out when the film was taken. The two behaviors differed significantly. At some later time the concerned astronauts, who had again received a message from me via Walter Cronkite, had given small pieces of their steak to the animals. The reports indicate that the spiders rejected these, cutting them out of the webs. Soon afterwards web-building ceased completely, which did not surprise me. The late webs, of which we have sample photographs, were small and irregular. They were probably built by starving animals. We have no evidence that any other deleterious conditions prevailed, or that they suffered from the long stay in space.

Mrs. Mabel Scarboro, who had had experience with web measurements in my laboratory for years, extracted whatever information was possible from the incomplete photographs. The webs had actually been larger than the pictures, and we were unable to measure whether their size was in excess of Earth webs. But we could judge the angle sizes between radii in the space webs and compare them with known data, which had been determined from hundreds of webs on Earth. While on Earth, there is a distinct difference in size between the angles in the upper part of the web and the lower part, the space webs showed no difference. The bottom angles, which are normally smaller than the ones on top, were now equal (as far as any "bottom" could be established). It seems that when there was no gravity as a cue, the north-south web symmetry disappeared.

Only part of the spiral could be measured in the space webs. In the first webs there was no difference in regularity as compared to controls; later the spirals became highly irregular. Twenty years earlier I had measured spiral distances and speculated about their logarithmic spacing. The conclusion at that time had been that the orientation was according to the shortest distance from radius to radius, which means that the spider uses the perpendicular from one radius to another. This is a relatively easy and quick way of orientation, which results in a logarithmic spiral (Behaviour 4: 172-189, 1952). When absence of gravity showed no influence on the logarithmic spiral, the earlier surmise was confirmed. It had taken 20 years until new evidence confirmed the old assumptions.

We found fewer turning points in the space spiral, in distinction from the Earth spirals. This may have had to do with the roundness of the space web, which filled a frame which was closer to a square. The measurements of thread thickness, which could only be made approximately on photographs (by David Peakall), rather than on the threads themselves, showed the expected thinner threads built in space. It could be the opposite effect of the one we found with weighted spiders on Earth. It confirms my earlier guess that spiders can perceive their body weight and regulate the thickness of extruded thread accordingly.

The most frequently asked question is: what can we really learn from the spider experiments in space?? This always reminds me of all the missed opportunities, which were the result of a lack of communication with NASA, and the poor photography. Then I remember how admirably the two spiders performed in space, and how that increased my respect for the small animals. They were brought into a foreign environment where some of the cues, which they and their ancestors had always used, were missing. Under such adverse circumstances they had constructed a large, efficient trap for prey, a slightly changed but still effective geometric orb web. Only a few days of trial and error were required to adjust to the abnormal environment. Under other circumstances they would have survived by catching the accustomed airborne prey. As in experiments before, I had found that backup mechanisms made their behavior much more flexible than usually expected.

A lesson can be learned from the interaction between NASA and myself: a large organization which is changing sources of support is an awkward partner in the preparation of experiments. The only person who had been able to cut twice through the red tape was a well-known TV anchorman, not a scientist. I was probably less surprised than many others when later preparations for a launch into space went wrong. In decision making and planning many minds do not necessarily function better than one. Through patience and diligence we finally obtained some new insights into spider behavior. Much more could have been learned if closer coordination between the Earth laboratory and the astronauts could have been achieved.

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THE AMERICAN ARACHNOLOGICAL SOCIETY
FINANCIAL STATEMENT
First Quarter, April 11, 1989

Balance from 29 December 1988		$19,997.84
DEPOSITS		
Membership dues	9161.00	
Sales of Platnick and Brignoli Volumes	5570.00	
Sales back issues	45.00	
Spider Genera, note cards, Linyphiids	605.50	
Donation from Jim Berry	190.00	
Page charges	863.75	
Interest	278.50	
Subtotal:	$16,713.75	
EXPENSES		
Texas Tech JA 16(2)	7132.95	
Texas Tech JA 16(3)	5903.80	
Texas Tech, mailings and "Instructions" reprint	245.35	
Postage, Dept. Zool, UT, back issues	75.80	
Postage, Jon Reiskind	51.40	
checks returned from sales	20.00	
Subtotal	$13,429.30	
Total Assets:		$23,282.29

Gail Stratton, Treasurer

More Information on Collecting in Mexico

Linden Higgins
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Mexico can provide many opportunities for both the ecologist and the systematist of arachnids. Although regulations have become stricter in recent years, especially for collection in the national parks, the "tramites" should not inhibit the exploration of the incredible diversity of habitats in this country. Current research is being conducted on arachnids in Nuevo Leon, Baja California, Jalisco, Michoacan, Puebla, Veracruz, and Chiapas by investigators associated with the National Autonomous University of Mexico (UNAM) and other Mexican institutions. Many of these sites are very peculiar, such as the National Park Tehuacan (Puebla), a high-altitude desert possessing tropically-associated fauna and flora, and the forests of Chamela (Jalisco), the driest tropical forest yet studied (less than 1 m rain per year). Except in Baja California and Chiapas, the non-acarid arachnological fauna is almost unknown and the results of a few days spent collecting can be very exciting (19 families collected in two months in Los Tuxtlas, Veracruz; 21 families collected in three months in Chamela, Jalisco).

There are several options for conducting research in Mexico. The Instituto de Biologia, UNAM, has two field stations which are well equipped (air conditioned laboratories, small libraries, resident staff) and easily reached by bus from the City of Mexico, Chamela, Jalisco and Los Tuxtlas, Veracruz. Visits to these stations are arranged by submitting research proposals and dates to the Secretaria Tecnica (Instituto de Biologia, UNAM, A.P. 70-233, Cuidad Universitaria, C.P. 04510). A second option is through SEDUE, the Mexican national park system. This is an option with the most paperwork, but is the only access to the various national parks and is that described by Marsha Conley in the November 1988 newsletter. To deal directly with SEDUE, one corresponds with the Secretaria de Desarrollo Urbano y Ecologia (Av. Constituyentes No. 947, Edif. "B", Col. Belen de las Flores, Mexico, D.F., C.P.01110). As described by Dr. Conley, association with a Mexican institution or investigator is one of the requirements. However, this requirement suggests a third and, I believe, preferred alternative: direct association with a Mexican researcher. There are many arachnologists currently working in Mexico, especially in taxonomy and mites, and there is a growing interest in ecology and behavior. Several of these researchers are members of the AAS or of the Mexican Entomological Society (Sociedad Mexicana de Entomologica, A.P. 7-1080, Mexico, D.F.; C.P. 06700), and can be contacted through these societies. I do suggest that all correspondence be sent in duplicate to avoid confounding problems by lost letters.

Even if one decides to work independent of a Mexican institution, I strongly suggest that visiting researchers take time to visit, perhaps to give a seminar. Relationships have been strained in part by the lack of direct communication of information gathered by foreigners that visit, and the best way to reduce these problems is through visits. The local researchers are enthusiastic, helpful, and can provide information on when to find specific animals.

U.S. and Canadian arachnologists should not immediately reject the idea of research in Mexico. It is a wonderful and rich country, with a rich diversity of habitats and cultures that more than compensate for the paperwork sometimes required. And one additional benefit of arachnological research in Mexico is that most sites of arachnological interest are close to sites that are of archeological and/or anthropological interest, greatly increasing the value of one's trip. I am willing to provide further information about various sites, the logistics of working in Mexico with or without private vehicle, the "tramites" of visas, equipment (anything electronic can cause difficulties), SEDUE and the Instituto de Biologia stations. Send correspondence to: Centro De Ecologia, UNAM, Apartado Postal 70-275, Ciudad Universitaria. C.P. 04510.

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RESEARCH REPORT

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My major upcoming spider project is an article for Ann. Rev. Ecol. Syst. on "Function and phylogeny in spider webs", and I would like to take this opportunity to ask those of you who have papers and/or manuscripts on these topics to please send me copies so I can include as much of the relevant literature as possible (and not neglect to cite papers by friends). Thanks.

Other projects under way include a study of the attack behavior of my favorite species, Leucauge mariana, combined with a study of the escape behavior of one of its prey (a sepsid fly), and the mating system of several species including Gasteracantha cancriformis (currently in the midst of a huge population explosion on the Pacific side of Costa Rica -- once again the stable tropics prove not to be so stable), L. mariana, L. argyra, and perhaps a pholcid (the idea is to check on the importance of female spermathecal anatomy in determining male behavior). I continue to be interested in the function of genitalia and copulation in general. Extra-arachnological projects include coital courtship behavior and genital mechanics in several beetles, the medfly, and earwigs, the evolution of bacterial plasmids, and the functional anatomy of male earwigs' forceps.