Proposal Overview

Application

Ref. Number	ILSRA-2009-1049	Submission date	12/09/2009

Proposal Details

Call	**International Life Sciences Research Announcement: Research Opportunities for Flight Experiments in Space Life Sciences on the ISS (ILSRA-2009)**
Proposal Title	**3D Spider Web in Microgravity**
Acronym	**3DWEB**
Keywords	**Spider; Neuroscience; Behavior; Three-Dimensional Web**

Summary

Objective: The objective of this experiment is to study and compare the building behavior and structure of three-dimensional spider webs between microgravity and normal gravity. The hypothesis is that three-dimensional webs will differ in weightlessness compared to Earth, because the animals can no longer use their weight and the gravitational reference for sensing the up and down directions. It is expected that not only the webs will be different, but also the building process will be affected because of the alteration in the sensory-motor patterns of the animals after insertion into microgravity, like those observed in astronauts. However, after longer exposure to weightlessness, it is expected that the spiders will adapt their building strategy to the new environmental conditions and that three-dimensional webs will be more Earth-like. However, it is possible that the asymmetries often observed between the upper and lower parts of these webs on Earth will no longer be present after adaptation to microgravity.

Method: Six specimens of spiders from three different species will be flown in small vials. At regular interval during the six-month space mission (beginning, middle, end), one or two spiders of each species will be transferred to a housing for a web to be built. The web will then be scanned for three-dimensional analysis. An on-board laser-supported tomography method will be used to record successive pairs of image planes. The images will be compressed and downlinked to Earth for a complete photogrammetric analysis of each thread end nodes. This will allow a digital reconstruction of the space web in 3D. Post-flight analysis of web samples for evaluation of thread diameter and stress-strain characteristics will also be performed.

Expected Result: Understanding the three-dimensional structure and building behavior of spider webs and the role of the environment in their design and robustness addresses questions in arachnology concerning the evolution of webs, prey capture behavior, foraging theory and plasticity in behavior. This research also has numerous applications in various scientific fields such as chemistry, sensory physiology, ecology, engineering, architecture, and art.

Area(s) of Research

Life Sciences / Human/Animal Physiology / Neurophysiology

Human Subject

Does this proposal involve experimentation on human subjects?	**No**

Project history

Has this proposal (or similar) been submitted to any agency in the past?	**No**

Proprietary/privileged information

Does your proposal include any proprietary/privileged information?	**No**

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Date: 12 September 2009

Research Proposal in Response to the International Research Announcement for Research in Space Life Sciences in the International Space Station – ILSRA-2009

Proposal Name: 3D Spider Web in Microgravity (3DWEB)

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1 Project Description

1.1 Objective and Hypothesis

The objective of this experiment is to study and compare the building behavior and structure of three-dimensional spider webs between microgravity and normal gravity. The hypothesis is that the behavior (strategy and duration) of the spiders for building three-dimensional webs will differ in weightlessness compared to Earth, because the animals can no longer use their weight and the gravitational reference for sensing the up and down directions. It is expected that not only the webs will be different, but the building process will also be affected because of altered sensory-motor patterns in the animals after insertion into microgravity, like those observed in astronauts. However, after longer exposure to weightlessness, it is expected that the spiders will adapt their building strategy to the new environmental conditions and that three-dimensional webs will be more Earth-like. However, it is possible that the asymmetries often observed between the upper and lower parts of these webs on Earth (Benjamin and Zschokke 2003) will no longer be present after adaptation to microgravity.

Understanding the three-dimensional structure and building behavior of spider webs and the role of the environment in their design and robustness address questions in arachnology concerning the evolution of webs, prey capture behavior, foraging theory and plasticity in behavior. This research also has numerous applications in various scientific fields such as chemistry, sensory physiology, ecology, engineering, architecture, and art.

Since ancient times spider webs have been inspirations for science, engineering, art, and architecture. As an architect, Tomas Saraceno is drawing analogies between the structure of a three-dimensional spider web and the net structures that he uses to visualize the origin of the universe (Figure 1). A previous example of nature-inspired building based on spider web is that of the Olympic Stadium in Munich, which was designed by architect Günther Behnisch and engineer Frei Otto based on the structure of the orb web-spider *Cyrtophora citricola*. During a research for an exhibition at the Venice Biennial 2009, one of the most renowned art exhibitions in the world, Studio Saraceno and TU-Darmstadt developed an original method for capturing data and visualizing the three-dimensional structure of a spider web.

Figure 1. Exhibition by Tomas Saraceno at La Biennale di Venezia in 2009 of a "Galaxy forming filaments, like droplets along the strands of a spider's web". Source: http://www.nytimes.com/2009/06/08/arts/design/08roun.html?_r=2

Based on this data, Tomas Saraceno realized in the Italian Pavilion, the largest solo space at the Venice Biennial, a complex structure of lines, which was largely inspired by his research on spider webs (Figure 1). This exhibition has attracted over 150,000 visitors since its opening on 7 June 2009. Tomas Saraceno and Adrian Krell from Studio Saraceno will also use this data for building a complete blown-up three-dimensional structure in an exhibition at Bonniers Konsthall in Stockholm, Sweden in spring of 2010. It is foreseen that the information collected during the proposed ISS experiment will be utilized in future exhibitions and designs.

Spider webs can be grouped into three general classes (Shear 1986):

1. Orb webs are two-dimensional "cartwheel" structures of geometric design. The circular orb serves as a catching surface. Orb webs may be vertical, as in *Araneus*, or horizontal, as in *Leucauge.*

2. Sheet webs are two-dimensional webs with little or no symmetry. Most are horizontally oriented. The catching surface may be flat, convex, or concave. Sheet webs tend to be long-lasting structures and are resistant to environmental or prey-induced damage. *Agelena* is an example of a spider building horizontal sheet webs with these characteristics.

3. Space webs are three-dimensional structures, and can be based on orb, sheet, or tangle webs. Space webs are built by a variety of spiders, including *Latrodectus*, *Steatoda*, *Achareanea*, *Linyphia,* and *Cyrtophora* (Figure 2).

Figure 2. Photograph of a three-dimensional spider web built by a linyphiid spider. In these webs, the spider walks upside down on the lower surface of the sheet.

While there are numerous studies on the structure of two-dimensional webs (see Zschokke & Vollrath 1995 for review), only a few studies have investigated three-dimensional spider webs. In a recent study by our group, the strategy used by a theridiid spider such as *Steatoda triangulosa* for building a three-dimensional web was studied (Benjamin and Zschokke 2002). These spiders build a complex net often described as "irregular". The web consists of supporting structures and lines under tension termed "gumfooted lines". Web construction lasts several nights. After orientation, the spiders build a three-dimensional structure of several threads radiating sideways and downward from the retreat. To build gumfooted lines, they start from the retreat, move along a structural thread, then drop down to attach the thread to the lower substrate. On returning, they coat the lowest part of the thread with viscid silk before moving up along the same thread back to the structural thread. They then continue moving along the same structural thread to drop down again to build the next gumfooted line. This behavior is continued until the spider has built a series of gumfooted lines (a bout). There are regular intervals between the construction of two bouts. Thus, a single web includes many bouts built in different stages (Benjamin and Zschokke 2002). Recent results show that gumfooted lines are not homologues to sticky web elements of orb-weavers and present synapomorphic characters that are different from orb-web weavers.

Some wolf spiders living at the edge of ponds can run away over the water; they return to solid ground by using visible landmarks or, if these are absent, astronomical cues such as the polarization pattern of the sky or an internal guidance system, often referred to as idiothetic memory (Barth 2002). Whether the necessary information is collected internally or externally, on site or en-route, the behavior of the funnel-web spiders clearly shows that they use a variety of cues and mechanisms to orient and navigate.

Because in microgravity the spiders can no longer use their weight, the directions of up and down, or astronomical cues to design and construct their web, significant differences should appear in three-dimensional webs built in orbit compared to the same web built on Earth. Previous studies have been carried out in space during Skylab, Spacelab, and ISS missions (see section 1.3.1 below). However, these experiments were student experiment projects (K-12), with limited controls and simple recording equipment. Consequently, the crew time was extremely limited, the observations made were anecdotal, and most of the data never got published in scientific journals. In addition, the spiders used in these previous space studies were orb-weavers, whose webs were mostly two dimensional. In addition, the upper and the lower part in orb-webs differ only in shape and not in fundamental structure, as it is the case in three-dimensional webs.

In the present experiment we propose to use spiders that build three-dimensional web structures. Based on recent discoveries that perception of depth and height is altered in microgravity (Clément and Eckardt 2005, Clément et al. 2008a, 2008b, Clément and Bukley 2008, Clément et al. 2009a, 2009b, Villard et al. 2005) and that there is an alteration in the mental representation of physical space when the gravitational reference is removed (see Clément and Reschke 2008 for review) we hypothesize that the spiders will behave like the astronauts during exposure to microgravity. Consequently, the shape and the speed for building three-dimensional webs should be affected during early exposure to microgravity. However, after longer exposure the animals should use other strategies to build the same three-dimensional webs as on Earth. In fact, it is even possible that the webs built in space after complete adaptation be the most perfect three-dimensional structures. A detailed analysis of the strategies used by the spiders to build these perfect webs and their final design will be extremely useful for arachnologists, architects and engineers. For this reason our team is composed of professional arachnologists, space physiologists, engineers, architects, and artists.