Teaching Science "Spiders in Space Experiment" on Columbia STS-107

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Abstract*: The tragic loss of Columbia and her crew on 1st February 2003 stunned the world as debris was scattered over the Southern United States. This event was in stark contrast to the well wishers and clear blue sky that engulfed Space Shuttle Columbia STS107 as she took off on the 16th of January with eight Australian spiders on a sixteen-day mission into space. Students of the Glen Waverley Secondary College with RMIT University and the Royal Melbourne Zoo designed the experiment[10]. This process has led the students into direct contact and collaboration with established space entities NASA, Bioserve and Spacehab as well as international researchers. The class activities include the design of the experiment and investigations into issues such as life-support, flight clearance and mission simulation.*

The hypothesis tested whether spiders can build orb-webs in Microgravity conditions, and how Microgravity affects the web structure, method of production and quality of silk.

Despite the tragic loss of Columbia and her crew during the STS107 mission, the STARS experiment has yielded some insight that has assisted biological researchers in investigating the effect of micro gravity on the health and behaviour of spiders for the development of space a "Greenhouse". The development of habitat and automated feeding for spiders and similar life forms also provide valuable experience and insights into supporting life in space. The project demonstrates that being part of real-life space science and exploration is now a possibility for all young Australians.

Keywords*: education, science, innovation*

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Introduction

Examination by NASA of early shuttle missions flown found that there was often excess payload capacity either in mass or volume. NASA realised that many small experiments could be accommodated within the orbiter's spacious payload bay, offering opportunities for schools to fly experiments. NASA initiative enabled a number of schools in the U.S.A. to play an active role in space research.

In 1998 SpaceHab Inc (USA) offered commercial learning package internationally for school experiments on the Space Shuttle. The program known as Space Technology and Research Students or S*T*A*R*S. The second S*T*A*R*S experiment was flown on STS-107, in January 2003 the participating schools[10] included the United States, Australia, Canada, Japan, China, and Israel[5]. This program was made possible by NASA's development of small payload containers to conduct a variety of space experiments[7], these experiments have a typical launch mass of less than one kilogram. Engineers and scientists from Bioserve at Colorado University, develop support hardware for the S*T*A*R*S experiments under contract to Spacehab Inc. Each experiment is assigned a container of specified dimensions and a place within the payload locker Figure 1.

Figure 1: The payload locker showing the spider experiment habitat, Assoc Prof Lachlan Thompson demonstrates how the astronauts took web samples during the mission

Each class, supported and mentored by a scientist(s) was responsible for experimental development and liaison with the launch provider. The class working with Spacehab to fulfil mission flight clearance requirements. The class was then provided with access to live and recorded mission data and a supporting curriculum from Spacehab.

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Spiders in Space

The Australian S*T*A*R*S experiment on STS107, "The effect of microgravity on spider behaviour' was proposed by RMIT University[2] in response to a State Government Competition to find both an experiment and a class to participate in the Spacehab Science, Technology and Research Student (S*T*A*R*S) program.

The experiment being designed to be compatible with the Curriculum Standards Framework[1] (CSF-II) for years 7-12. The teacher selected to host the first Australian school space experiment was Ms. Caroline Need and her year 9 science students from Glen Waverley Secondary College in Victoria.

Figure 2: Glen Waverley Secondary College student Greg Carstairs from prepares the spidernauts food (fruit flies) at the Astrotech Facility Florida, preparing the experiment.

The GWSC class together with their teacher and researchers from RMIT University[10] and the Melbourne Zoo formed the core research team, or "Nova" class as used in the S*T*A*R*S program. The class of twenty-six students from year 9 is assigned into specialist research groups dealing with experimental design, spider husbandry, communication and collaboration with external researchers. Students are given specific research tasks for which their team has ownership and responsibility.

Students were required to interact with Spacehab in the USA through the protocols of experiment approval, hardware definition, live materials list, experimental protocol, "delta phase three" clearance (flight approval), and mission simulation. The experiment was originally to fly in December 2000, but due to a number of delays with modifications to the Columbia Orbiter Flight Vehicle the STS107 mission did not fly until three years later, with the launch on 16th January 2003. The long project delays meant that the student program had to be extended to keep the class involved in the experiment. The role the RMIT University in maintaining the program through this longer period was essential to the completion of the project. On completion of all milestones the experiment was to be shipped to Mission preparation centre at the Kennedy Space Centre.

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Figure 3: Columbia taking aloft the dreams of discovery of the Glen Waverley students.

The STS107 Experiment

The STS107 Columbia Figure 3, spider experiment examines the effect of microgravity on the behaviour of spiders and the properties of their webs. This topic was chosen for its accessibility and appeal to students across a broad range of ages and capabilities. The experiment aims to add to the current body of knowledge concerning the biological effects of microgravity on living organisms with particular focus on web-building and the microstructure of spider silk spun in microgravity. Some insight into the suitability of spiders as pest control agents in a micro gravity greenhouse is also being investigated with the long-term application to a human mission to Mars.

Gravity is believed to have a strong influence on spider behaviour, particularly the way they move and build their webs. Gravity is thought to influence the thickness of their silk, the 'North-South' asymmetry of their webs and assist them to orient themselves, particularly in rebuilding webs that have been disturbed during the web-building process.

Figure 4; Left Australian spidernaut 'Slayer' training for the mission.

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The spiders were monitored during day and night with still and video camera. The night photography was the most useful as the spider is nocturnal. Excellent images of the spider during its web making were taken. This allowed the class to examine the spider's web making prowess. While eight spiders flew on Columbia a second spidernauts team were undergoing the control experiment in an identical locker box and habitat.

Figure 5: Israel's first astronaut, mission specialist Ilan Ramon prepares to take a web sample on day 8 of Columbia's mission. (Photograph courtesy NASA)

To identify the spiders between the two groups they were each given a unique name. The lead spidernauts on the Columbia flight was "Wako" which is an Australian Aboriginal name for spider. The lead spidernauts on the ground-based control was "Cadbury". Observation of the Spider Habitat included video and measurement of Temperature, Day or night cycle phase and humidity, Figure 6. The charts shown below are taken from Day seven of the mission. The temperature in degrees Celsius varied through out the mission from 24 degrees C to 26.5 degrees C with an average Humidity of 60%. A humidity of 60% is a wet or moist atmosphere well suited to invertebrates (spiders and flies).

One of the operation problems with the experiment was that the spider is nocturnal. The other experiment in the isothermal module is daylight. In shuttle operations flights work on an 18 hour day with 12 hours daylight and six of night. This had the effect of reducing the quantity of useful data available to the researchers.

In both habitats the spidernauts were to be fed by the hatching of fly pupa laid in agar gel at the base of the spider habitat. Observations by mission specialist Ilan Ramon[11] confirmed that the biological feeder was working correctly. Analysis by the students of the downloaded experiment photography is being carried out to determine spider feeding activity. Analysis of the spider web pattern shows that the microgravity spidernaut made a more circular web than its earth bound control spider.

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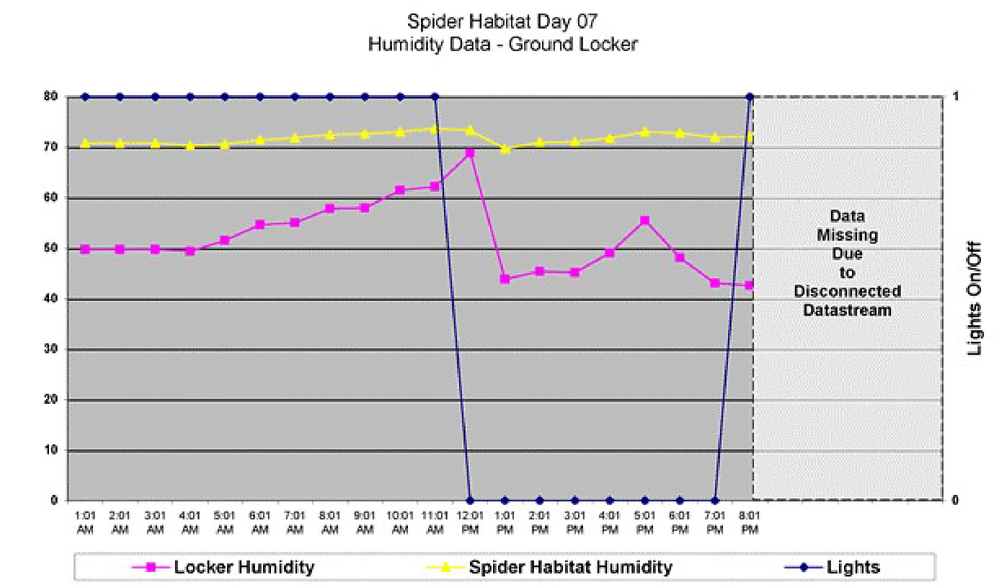

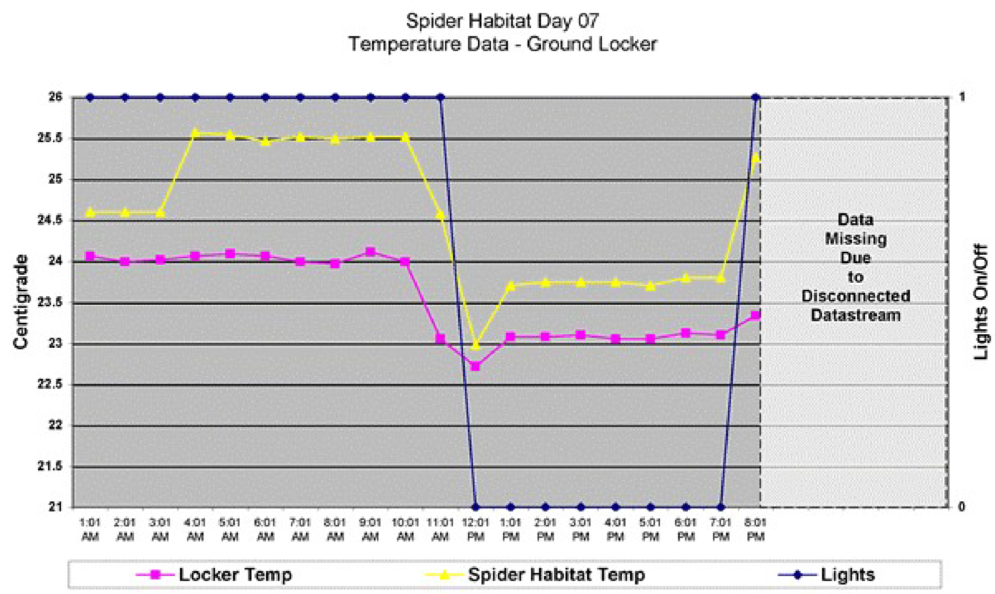

Figure 6: Humidity and Temperature Data charts were used by students to monitor the spider environment. Note the data stream failure.

Comparing the performance of the two lead spiders showed that "Wako" in Microgravity was able to construct her web in just over half the time of its land-based control "Cadbury". The video available of "Wako" show the spider deftly manoeuvring on the web compared to the earth bound "Cadbury". Other differences in web shape were observed supporting observations made by "Skylab 3". Analysis of the results has been hampered by the tragic loss of Columbia and her crew.

Research Outcomes

The science of the experiment has application to space life sciences where in order to conduct interplanetary human space colonisation bioenvironmental controls will be required to ensure a sustainable environment for the crew. Investigation and development of life support

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systems for spiders and similar life forms in space could contribute to knowledge necessary for supporting ecosystems in space.

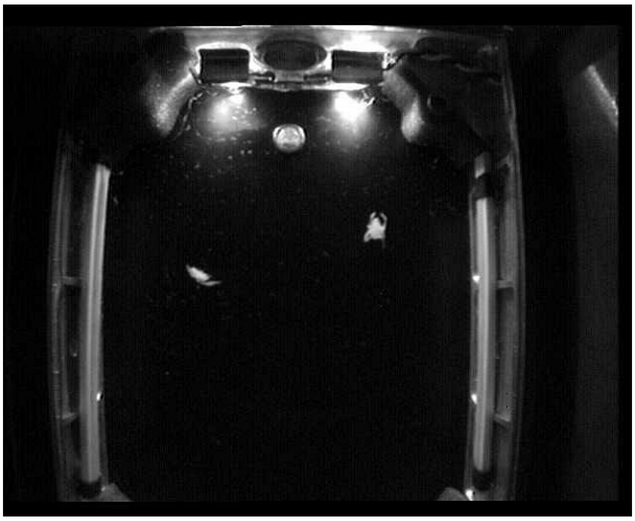

Figure 7: Poised in micro gravity aboard STS107 Columbia Aussie Spidernauts Wako (right) and Jenny (left) weave orb webs.

Observing how the spiders learn to move without the aid of gravity and develop new techniques for web building could possibly yield insights into techniques for building structures in microgravity. For example the two-dimensional nature of the spider-web is comparable to the large planar structures used to support solar and other arrays. Greater understanding of the construction and dynamics of these inherent 2D structures will facilitate the design and development of vast arrays to support future orbital space habitats and robotic devices required to construct them.

Educational Benefits

The students selected for the Spider project were taken from year 8 based on a typical grade distribution for that year of students. Twenty Six students joined the program on the basis that the S*T*A*R*S class was an additional load above normal year nine class work. In developing their hypothesis and designing their experiment the students of the NOVA class have gained insight into the role of science in our community. The students worked with telemetry data in a professional technical environment and budgets. The students conducted independent research activities and developed problem-solving skills to real-life situations. Some of the concepts that the students encountered during the course of the project include:

- The relationship between weight perception and web structure and microstructure.
- The role of gravity in orientation and web building/rebuilding.
- Adaptation to and movement in microgravity conditions.
- The phenomenon of fluid shift and other aspects of health in space.
- Spider biology and behaviour.
- Experimental techniques, and validation.
- The use of Clinorotation to simulate weightlessness.
- Running an experiment with minimal human intervention and contingency planning.
- Building a mini-space ecosystem, the development of a biological feeder.
- Life support needs to be met in a space environment.

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- Shuttle missions: procedures, deadlines, and simulations, live materials list awareness of factors influencing shuttle launches.
- Objective analysis of experimental results.
- Working with professional scientists, astronauts and technicians to solve complex problems of science.
- To communicate the results of experiments to the professional scientific community.
- That science is an adventure and challenge at the frontiers of human achievement that drives individuals and teams, the pursuit of which is not without risk.

The 26 students worked with the project for two and half years leading up to the start of the VCE year when the team size dropped to 18 students for 2003. Comparing the student grade results to their comparative class and year groups the individual students in the program all achieved higher results than the expected. A detailed study is underway to quantify the academic performance of each individual student compared to their respective peers. This study will it is intended provide a quantitative measure of the educational experience.

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