JSC 24005

NASA/JSC INTERNAL NOTE

SHUTTLE STUDENT INVOLVEMENT PROGRAM (SSIP)
FINAL REPORTS
OF EXPERIMENTS FLOWN

NATIONAL AERONAUTICS AND SPACE ADMINSTRATION

Lyndon B. Johnson Space Center
Houston, Texas 77058
October 20, 1989

A COMPARISON OF HONEYCOMB STRUCTURES BUILT BY APIS MILLIFERA

(SE82-17)

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(SSIP Experiment SE82-17)

INTRODUCTION

Just what effect does gravity – or the lack of it – have on the structure of a honeycomb? Dan M. Poskevich was a senior at Waverly High School in Waverly, TN when he proposed an experiment called "A Comparison of Honeycomb Structures Built by Apis Millifera."

Dan went on to study electrical engineering in college. He credits SSIP with influencing his career goals by allowing him to work side by side with professional engineers. Dan says, "Working with my sponsor gave me a feeling of inner pride as to what really can be done when people work together."

This was not the first time that honeybees had traveled into outer space. Todd Nelson's "Insects in Flight Motion Study" researched the flight patterns of honeybees, moths and houseflies in microgravity.

A beehive's storage needs directly influence the building of honeycomb. A forager bee returns to her hive with a load of nectar, transferring it to the household bee to process into honey and store. If there is no place to store the honey, the household bee must retain it within her own honey stomach. If it remains there for many hours, most of the sugar content is assimilated causing wax scales to secrete involuntarily through the wax glands on the bee's underside. This creates the necessary construction material for comb expansion. (Butler 93) To build honeycomb in an enclosure, worker bees need an adequate food supply and a queen bee present. (Vandenburg et al 370)

Mel Coplin, corporate advisor Bob Peterson, Dan Poskevich and Bill Maben pose with the loaded BEM.

CONCEPT

The objectives of Dan's experiment were two-fold:

- Monitor the behavior and survival of honeybees in microgravity.
- Compare the shape, size, volume and wall thickness of honeycombs constructed on-orbit to those built by a ground control group.

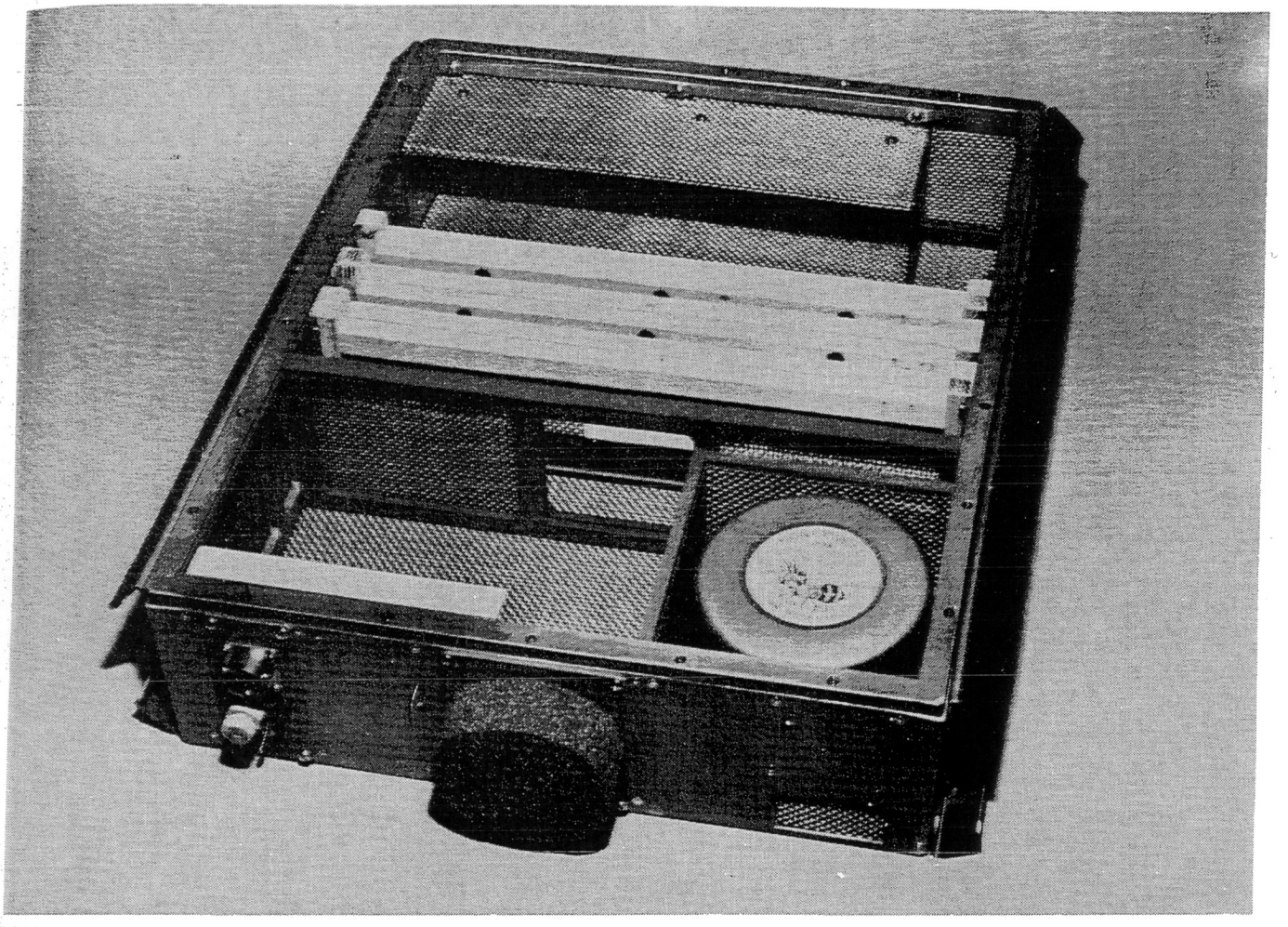
SPONSOR

As with Todd Nelson's experiment, the Space and Strategic Avionics Division of Honeywell, Inc. sponsored Dan's research. Dr. Robert Peterson of the Honeywell staff served as corporate advisor. The experiment flew aboard STS 41-C (Discovery) launched April 6, 1984.

EQUIPMENT

Dan originally proposed a cubic flight chamber containing two frames for the bees to use in constructing honeycombs. He suggested placing cameras at either side of the frames to continuously record the bees' comb-building activities.

The Bee Enclosure Modules (BEM's) were constructed of aluminum, with a Lexan top to facilitate photography. Each contained a feeder trough, three wooden honeycomb frames, a small flight chamber, a ventilation hole, a fan and two



The Bee Enclosure Module that flew 3500 "Space Bees" into orbit.

temperature probes.

Officials voiced concern that dead bees and bee by-products might create a hazard to the crew. NASA's extensive testing proved the BEM's filtration system adequate for containing any hazards.

The feeders contained a mixture of water, sucrose and agar. The agar provided a semisolid consistency to the sugar water mixture. This was necessary since in microgravity a liquid could bead up into free-floating droplets, useless to the bees and annoying to the crew.

This approach differed significantly from the feeders used in the Nelson experiment which consisted of Teflon tubes with a wicking, soaked in the food material, inside. These feeders had to also serve for flies and moths and may not have been practical for bees as all the bees in the Nelson orbiter flight box died. Analysis showed there was no disease or damage resulting from flight-related stress. Officials speculated death was caused by insufficient nutrition.

PROCEDURE

On April 5, 1984, approximately 3400 worker bees, with a caged queen, were placed in each of the two BEM's. The flight module was placed aboard the Shuttle at Kennedy Space Center (KSC) while the ground control module remained at Johnson Space Center (JSC).

The queen bees' cages were plugged with a mixture of powdered sugar and water. The worker bees consumed the plugs to release the queens.

Crew members observed the on-orbit BEM four times during the mission.

- April 6 (9 hours after launch) - Bees survived launch.
- April 9 - Video recordings and observations of bees and their behavior. Some bees attempted brief flights, colliding with the chamber walls.
- April 11 - Additional video recordings of bees and their behavior.
- April 13 - Final visual observations. Flight patterns show complete adaptation to microgravity.

Astronaut James Van Hoften observed the bees several times on-orbit. JSC personnel monitored the ground control BEM several times during the mission.

The ground control bees were removed from their BEM on April 12. Discovery landed on April 13 at Edwards AFB, CA. The BEM, with bees still inside, accompanied the flight crew to JSC the same day. The bees in the orbiter BEM were removed on April 14.

BEM, loaded with its 3500 tiny passengers

RESULTS

Dan used six sample pieces of honeycomb to estimate geometric parameters.

- Two pieces of comb attached to the Lexan top of the orbiter BEM.
- One piece of comb attached to a wooden frame in the orbiter BEM.
- Two pieces of honeycomb from a ground-based trial in September, 1983. (The bees at JSC built very little honeycomb during the STS 41-C mission, probably because of adverse temperature conditions)
- One piece from a hive in Beltsville, MD.

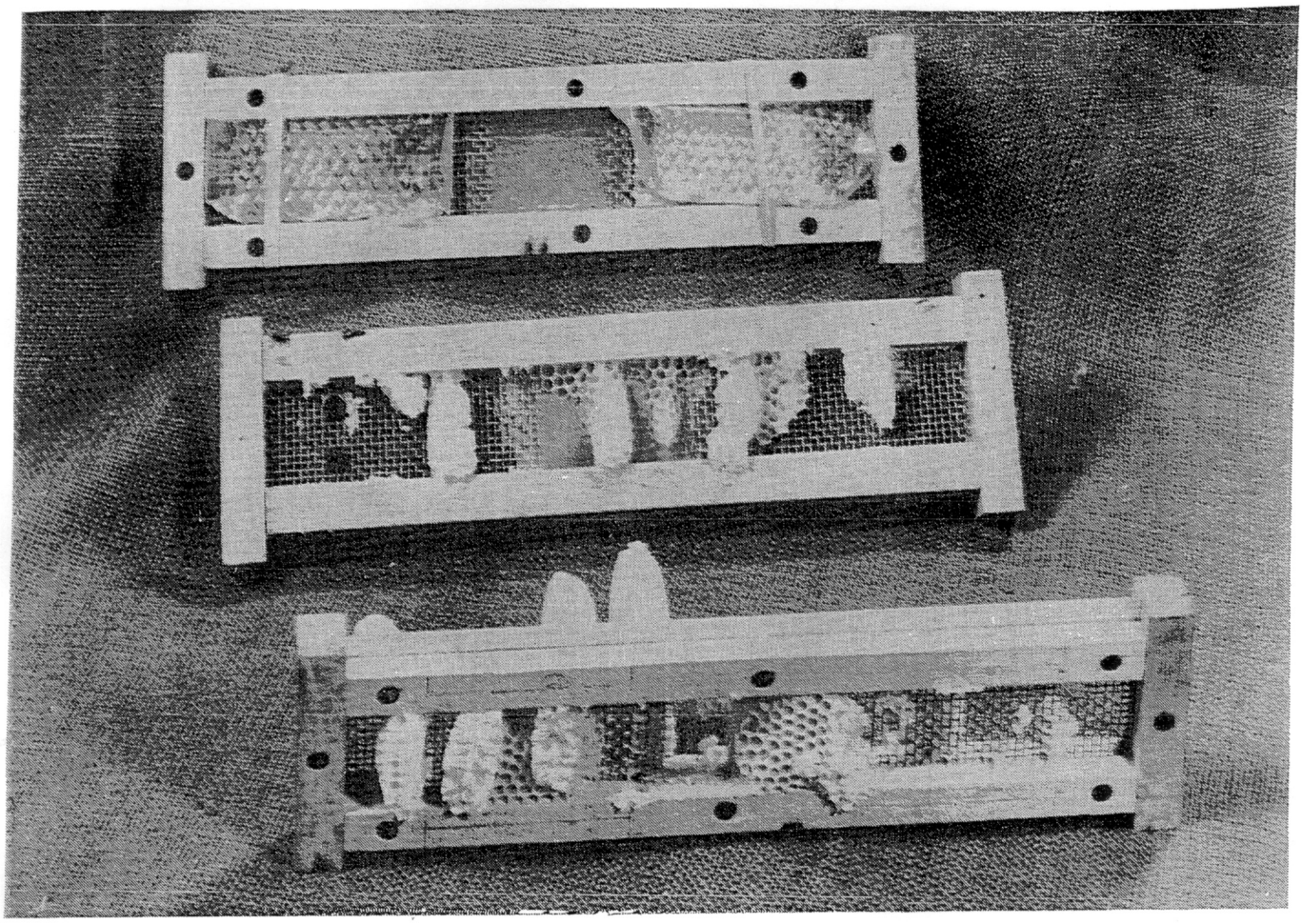
All but a few of the bees survived the week of confinement. 120 dead bees were removed from the orbiter BEM and 350 from the BEM at JSC. (Honeybees live for about six weeks on the average.) (Modern Maturity 64)

The queen bee in the orbiter BEM laid about 35 eggs. For unknown reasons these eggs failed to hatch when transferred to a standard hive near JSC.

The bees in the orbiter BEM produced about 200 cm of honeycomb. The bees used in the one-g trial run in September, 1983 produced more than 200 cm. For two of the orbiter comb pieces, cells on any one side were angled in the same direction. For the larger piece, cells on one side were angled up toward the Lexan top. On the other side they were angled down toward the BEM floor. The "up-angled" cells had a higher average angle than the "down-angled" ones. Of course the terms "up" and "down" in microgravity are only meaningful in relation to the BEM. Another piece, apparently started from the BEM floor, displayed a wide range of angles.

Average cell density was essentially equal for all pieces.

Mean cell depths ranged from 6.4 mm to 10.8 mm. Bees in microgravity did build comb cells of normal depth and use some to store sugar syrup.



Honeycomb structures built on-orbit.

The average cell diameters were smaller and wall thicknesses greater for comb built in microgravity.

CONCLUSION

The bees in the orbiter BEM fared quite well in outer space, managing by mission's end to adapt perfectly to flying in microgravity. The crew noted in the log book that "...by Day 7 comb well developed, bees seemed to adapt to 0-g pretty well. No longer trying to fly against top of box. Many actually fly from place to place." This adaptation may indicate a certain "learning" capacity on the part of the bees. The workers built honeycomb and stored sugar syrup. The queen bee in the orbiter BEM laid eggs. Reasons for the eggs' failure to mature are unknown and may have nothing to do with the exposure to microgravity.

The bees in the ground control BEM failed to build comb probably because they were too cold. A temperature of 33 to 36 degrees C is necessary for comb construction and, despite the efforts of the JSC personnel to warm the BEM, temperature ranged only from 21 to 29 degrees C.

Prior learning could have also played a part in comb construction. The experimental bees were all about 15 days old and may have already been involved in comb construction.

The investigators felt that any further study should be for a longer period to allow the queen's eggs to mature and use a larger flight chamber to allow more detailed observations of the bees' attempts to fly in microgravity. (Vandenburg et. al. 380)

GLOSSARY

Agar - Food thickening agent prepared from marine algae.

Apis Millifera - Scientific name for honeybees.

BEM - Bee Enclosure Module. Experimental fixture used as a beehive structure during the Shuttle mission to house bees.

Microgravity - Extremely low gravity level, as experienced by Shuttle crews. About one-millionth the level of gravity on Earth. The term zero-g(ravity) is often used where microgravity is the correct term.

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