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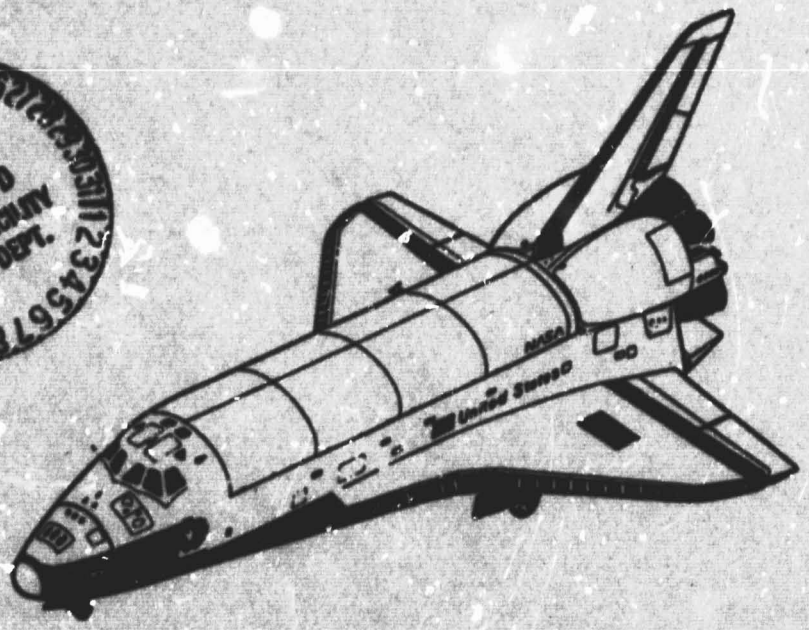
EXPERIMENT RESULTS: INSECT FLIGHT OBSERVATION AT ZERO GRAVITY



NASA
National Aeronautics and Space Administration

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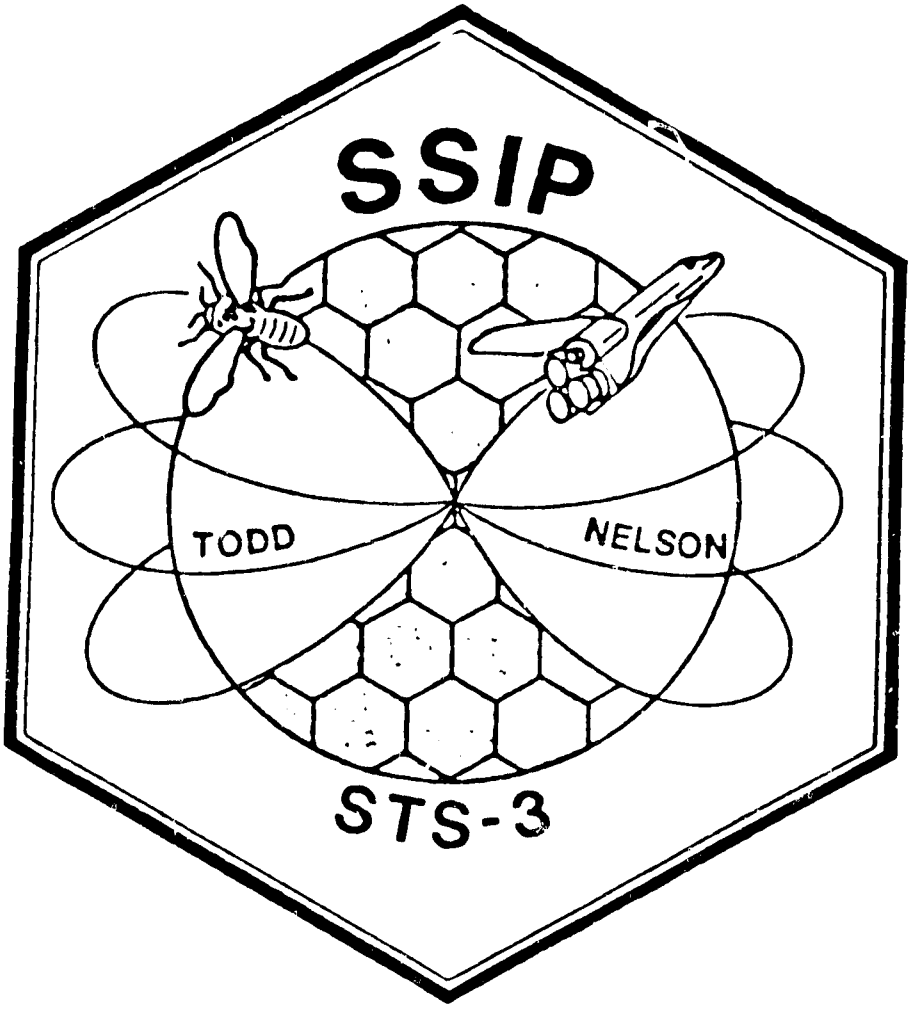

Insect Flight Observation at Zero Gravity

A Report Prepared for

the National Aeronautics and Space Administration and

the National Science Teachers Association

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INSECT FLIGHT OBSERVATION AT ZERO GRAVITY

ABSTRACT

The flight responses of common houseflies, velvetbean caterpillar moths, and worker honeybees were observed and filmed for a period of about 25 minutes in a zero-g environment during the third flight of the Space Shuttle vehicle (flight number STS-3; March 22-30, 1982). Twelve fly puparia, 24 adult moths, 24 moth pupae, and 14 adult bees were loaded into an insect flight box, which was then stowed aboard the Shuttle Orbiter, the night before the STS-3 launch at NASA's Kennedy Space Center (KSC).

The main purpose of the experiment was to observe and compare the flight responses of the three species of insects, which have somewhat different flight control mechanisms, under zero-g conditions. A control set of the three species of insects (drawn from the same laboratory populations as the set that flew on STS-3) was observed and filmed under normal gravity conditions at NASA's Johnson Space Center (JSC) to provide comparisons between zero-g and one-g flight behavior.

Ten of 12 flies aboard STS-3 were observed to have emerged from puparia by the third day of the flight (at about 55 hours after launch). Their activity in zero-g consisted primarily of walking on the interior surfaces of the flight box. When they flew, they tended to fly only briefly (with a maximum observed flight duration of four seconds). During the flight

observations, the flies appeared able to control their motion in all three of their body axes (pitch, yaw and roll) and appeared to have no difficulty flying from point to point in the box.

By the third day of the flight (at about 55 hours after launch), 18 of the 24 moth pupae aboard STS-3 had emerged. By the end of the eight-day flight, 22 of the 24 had emerged. The "young adult" moths which emerged from pupae during the flight were often observed to float, without wingbeat, for periods of five seconds to nearly three minutes. They also flew for short periods of time. The moths which were at the adult stage prior to launch tended to fly without engaging in floating behavior. The duration of floating of the "young adult" moths increased with time during the filming by the STS-3 crew. The moths exhibited some lack of control about their body pitch axes and were sometimes observed to tumble in pitch while floating or flying. However, they were able to control their body orientations to make "controlled" landings. An increase in flight velocity in the zero-g situation, with a given rate and amplitude of wingbeat, may have caused some flight control problems for the moths. The moths, like the flies, appeared to have no difficulty clinging to any of the interior surfaces of the flight box.

The 14 bees aboard STS-3 were observed to walk only on the screen surfaces inside the flight box. They appeared to be unable to cling to the smooth plastic surfaces. Brief attempts

at flight resulted in unstable paths, tumbling about their body axes, and floating with little or no wingbeat. Floating was observed for long durations and appeared to be a result of inability to cling to a smooth surface when they came into contact with it (with wingbeat ceasing at contact). The lack of relative-motion visual stimuli necessary to maintain flight may also have been responsible for the floating responses of the bees. In addition, it may have been that the food supply provided was inadequate for the bees and this may have led to fatigue with resulting poor flight control responses and floating.

Comparisons of the zero-g flight responses of the three species of insects suggest that the flies were most able to control their flight and body orientations. The moths appeared to be somewhat poorer at controlling their flight and body orientations than the flies. The bees appeared to be unable to control their flight in zero-g conditions and they were observed to mostly float about randomly in the flight box. Their floating behavior may have been due to several factors cited previously.

Post-flight analyses of the insects, after return to Earth, have indicated that:

- The total number of eggs laid per female for the flies that flew on STS-3 was lower than for the flies observed in the one-g environment at JSC,

- The moths did not mate in space but did mate after return to Earth and exhibited no appreciable decrease in fertility as compared to the one-g control group of moths observed at JSC,

- All 14 of the bees that flew on STS-3 were dead when the flight box was returned to JSC (about 8 hours following the STS-3 landing). Seven of the 12 bees observed in the one-g environment at JSC were also all dead at this time. Post-flight examinations and electron microscope analyses of several of the bees that flew on STS-3 indicated no disease or physical injury of the bees. It appears that the bees died due to lack of food.

CONTENTS

INTRODUCTION

This study was performed to obtain data on insect flight behavior during an extended period of zero-gravity on a Space Shuttle flight.

The opportunity to conduct this study was made possible through the Shuttle Student Involvement Project (SSIP) which is a continuing effort of the National Aeronautics and Space Administration (NASA) and the National Science Teachers Association (NSTA) to enable high school students to propose experiments to be flown on the Space Shuttle. The Avionics Division of Honeywell, Incorporated served as the Corporate Sponsor for this experiment. The experiment was flown on the third Space Shuttle test flight (flight number STS-3) during the period 22-30 March, 1982. The "SSIP Experiment Integration Plan" for this experiment (reference 5) identifies the requirements for conduct of the experiment.

Since, as noted by May, et al (1980), insect flight mechanisms are primarily adaptations for overcoming gravity (with most of the power output in flight comprising lift) it is of value to observe insect flight in the absence of gravity to better understand insect flight processes. The flight responses of flying insects in a continuous zero-gravity (zero-g) environment have not been studied previously because gravitational force cannot be eliminated (or even greatly reduced for an extended period) in such studies performed on

Earth.

Past experimentation on insect flight in zero-g environments has been limited to very short periods of weightlessness. May, et al (1980) conducted experiments on insect flight during short-term reduced (and increased) gravity levels by use of a Model 23 Learjet, flying parabolic paths to produce variations in gravity. Their abstract states:

> "Abstract - The tethered and free flight of Manduca sexta were studied during period 1, 2, and 0 times normal gravity (g) produced in an aeroplane by flying through parabolic trajectories. Moths in tethered flight did not change their aerodynamic output in response to increases or decreases in gravity. Some moths in free flight at 0g maintained a position in the box by flying against a surface, or into the angle between two surfaces. In the absence of gravity as an orienting stimulus, the positive dorsophotic response to light was dominant. As the period of 0g continued, moths were increasingly likely to periodically reduce the amplitude of their wingbeat and/or stop flying, for the equivalent of a few wingbeats. Only at 0g, moths very occasionally spread their wings and floated freely for a few seconds. At 0g moths retained control of rolling and yawing movements but stability in pitch was greatly reduced or absent."

The results of this study by May, et al helped to support and shape the hypotheses for this experiment by providing the only known previous data existing on insect flight in zero-g.

Hypothesis I

Insects will encounter problems in pitch orientation in zero-g conditions, depending upon the type of flight control mechanisms present in the species of insect observed.

Hypothesis II

In the absence of gravity, flying insects will be attracted to, and fly in, the area of the brightest illumination in the flight box.

INSECT SUBJECTS

Three species of flying insects were selected to observe and compare their ability to orient and fly in zero gravity (zero-g) as well as one gravity (one-g). The insects selected were: Worker Honeybees (Apis mellifera), Velvetbean Caterpillar Moths (Anticarsia gemmatalis), and Common Houseflies (Musca domestica).

The bees were all in their adult stage (about 6 days old) when they were loaded into the experimental insect flight box prior to launch. Both adults and pupae of the moth were loaded into the flight box (with the pupae "scheduled" to emerge on orbit prior to the planned experimental observations). The adult moths were 1-2 days old. All of the flies were loaded into the flight box as puparia (also "scheduled" to emerge prior to the experimental observations).

The bees had their stingers "clipped" to prevent any hazard to the flight crew in the event that any bees escaped from the insect flight box and got out into the Orbiter crew compartment. The bee supplier clipped several thousandths of an inch from the tip of each bee's stinger prior to delivering the bees for use in the experiment.

The criteria for selection of the insect species to be studied included such things as physical size, life span, food requirements, and the ability to fly well in the volume provided within the insect flight box used in the experiment.

Items considered were:

- The insects had to be available from a reliable source (i.e., a source that would provide healthy insects of controlled ages from common populations within species).

- For purposes of data collection, the size and wing span of each insect had to be large enough to show up clearly on recorded video and in photos for data analysis.

- The adult (active flying) life span had to be greater than 9 days. This allowed data collection on any day of the planned Shuttle mission, in case the scheduled observation day was changed. It also provided an allowance for a several-day postponement of the STS-3 launch.

- Species with similar food requirements were needed to simplify the feeding apparatus and food/water sources provided inside the insect flight box.

- The species selected had to be compatible with each other (i.e., would not attack each other).

- The species selected had to have flight characteristics that would allow them to fly normally within the constrained volume of the insect flight box.

Since any single species of insect could have died prior to data collection (e.g., may not have survived launch accelerations), the success of the experiment was better

ensured by using more than one species. The use of moth pupae provided a supply of moths which emerged on-orbit to yield "young adults" prior to data collection. Since age can have an effect on insect flight activity, adults emerging from pupae provided younger moths whose flight behavior could be compared to that of the older adult moths. The use of moth pupae (and fly puparia) also provided data on the success of emergence and wing formation in zero gravity.

One of the reasons that common houseflies were selected for observation in the experiment was that they have halteres. Apparently, these halteres act something like "gyroscopes" or "gyrostabilizers" for flies to provide added flight stability -- at least in the one-g environment. It was felt that the halteres might also help provide better flight stability and control for the flies (as compared to the bees and moths) in the zero-g environment.

The insects used in the experiment were supplied by the following people and institutions:

- The Velvetbean Caterpillar Moths (adults and pupae) were supplied by Dr. Norman C. Leppla of the U.S. Department of Agriculture Insect Research Laboratory in Gainesville, Florida.

- The Worker Honeybee adults were supplied by Mr. Mel E. Coplin of Coplin Bee Farms in Arcadia, Texas.

- The Common Housefly puparia were supplied by Dr. David Pimentel of the Department of Entomology, Cornell University in Ithaca, New York.

EQUIPMENT/APPARATUS

The purpose of the insect flight box, shown in figure 1, was to confine the flight activity of the insects both for crew comfort and for data collection. Weight and size constraints (specified in the SSIP experiment integration guide, reference 3) were factors that shaped the design. A maximum of 60 pounds can be stowed in the two-cubic-foot storage volume of a standard Orbiter Mid-Deck stowage locker. The combined weight of the experiment insect flight box and the small size locker tray in which the box was carried (as shown in figure 2) was 6 lbs, 14 ozs. The maximum size of a box that will fit into the NASA standard small locker tray is 4.6 inches by 19.3 inches by 14.7 inches. The box used was 4.5 inches thick, 18 inches wide, and 14 inches high. Velcro pads on the back of the box were used to secure the box to the forward surface of the Airlock above the Airlock Hatch. Figure 3 is a cutaway view of the Shuttle Orbiter mid-deck (showing the locations of the stowage locker, airlock and airlock hatch). NASA-approved Lexan was used for the front, top, bottom, and sides of the box because of its transparency and strength.

The insect flight box was divided into two chambers (Chamber A and Chamber B) by a screened central divider. Each chamber was 4.5 inches deep, 9 inches wide, and 14 inches high (providing a volume of 567 cubic inches in each chamber). Screens in both sides of the box, and in the central divider, allowed air to

pass freely into and through the box.

The back of the flight box was aluminum sheet metal having a chromate treatment and was painted white with epoxy urethane. Black grid lines, one inch apart, were painted on the white surface to provide a visual reference for insects' positions during data analysis. Stainless steel screws were used to fasten the box together. Rivets were used to secure the aluminum screen in place on the sides and central divider. An insect feeder was located in each chamber. The feeders were made from hollow teflon tubes, one inch in diameter, having a 0.375 inch opening to expose a liquid absorbing cotton wick. This wick provided the surface area to dispense the sugar solution used as the insects' food/water source. Each feeder held approximately one fluid ounce of liquid when full.

Timers (one in each chamber) were used to provide a time reference on the 35 mm photos and recorded video. A Nelsonic Quartz, one inch diameter, timer was fastened to the rear wall of each chamber using a stick-on pad. Nomex material was used to make flexible loops, located at the sides of the box, to assist the removal of the box from the locker tray by an astronaut in space. The Nomex material was fastened to the box by two stainless steel screws.

NASA provided the on-board TV cameras, videotape recorder, video tape cassettes, and the on-board 35 mm camera, lenses and film that were used to collect data on insect flight behavior.

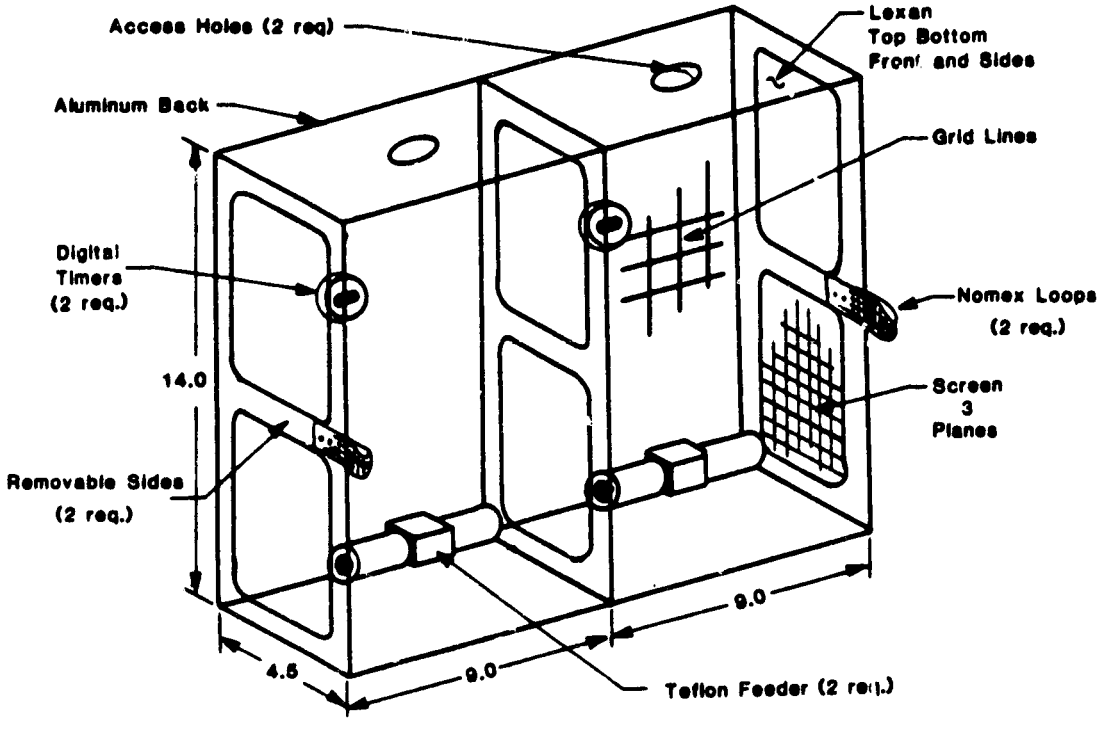


Fig. 1 INSECT FLIGHT CHAMBER

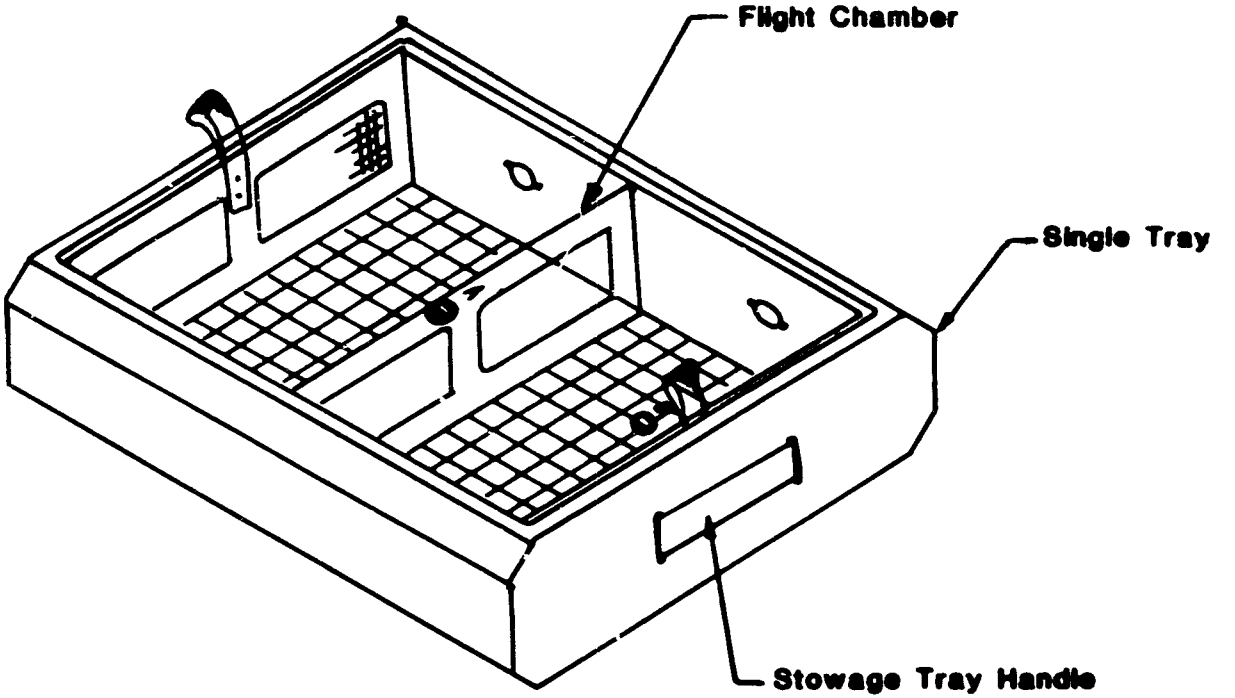


Fig. 2 Experiment Placed in Tray During Stowage.

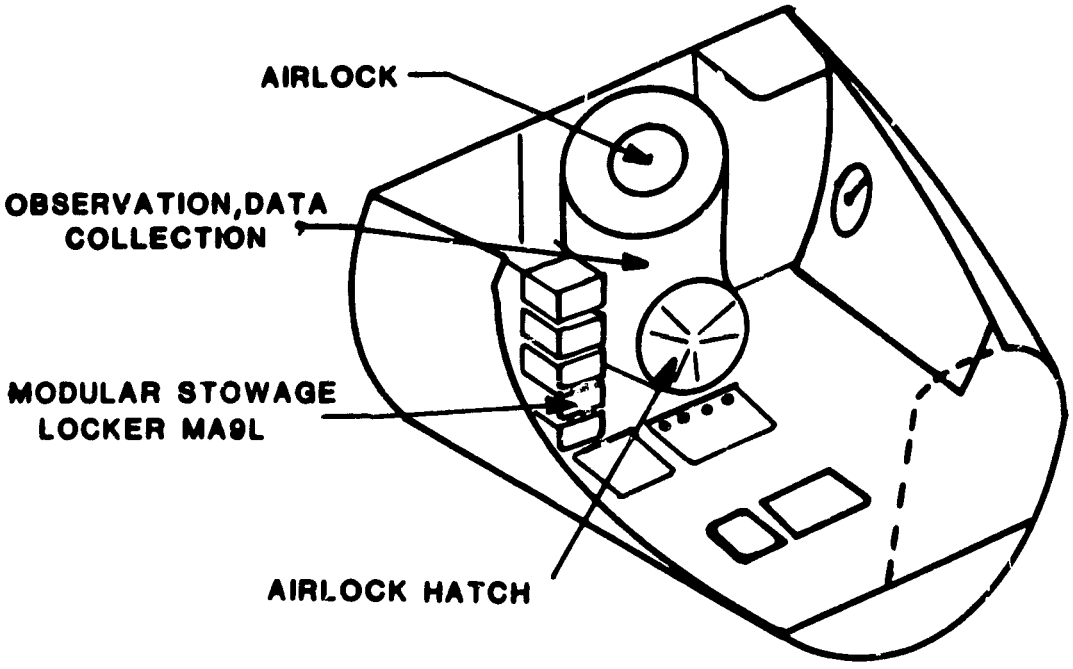


Fig. 3 The stowage ,obseervation and data collection location in the shuttle

PROCEDURES

Two separate sets of tests or observations of insect flight behavior were performed during the STS-3 flight. One set, the zero-g tests, were performed on orbit by the STS-3 flight crew. The other set, the one-g "control" tests, were performed in the hi-fidelity Mid-Deck Mockup at Johnson Space Center (JSC) by the author and JSC personnel. For each species studied, the zero-g test and one-g test groups of insects used were drawn from the same parent populations (to eliminate differences in age, genetic background, prior treatment, etc.).

The zero-g tests were performed twice on-orbit. The first tests were performed, as planned, on March 24, 1982 (during flight day three, about 55 hours after launch). The second tests, which were not initially planned, were performed on March 27, 1982 (during flight day six, about 125 hours after launch). The one-g tests were performed at JSC only once, on March 24, 1982, at the same time the first zero-g tests were performed.

Forty-eight Velvetbean Caterpillar (VBC) moth adults and pupae were used for both the zero-g tests and the one-g tests. Of these 48, 24 were adult moths (having emerged from pupae 1-2 days prior to launch) and 24 were pupae which were "scheduled" to emerge in zero-g, at about one day after launch, several days prior to the time for the scheduled tests.

Twelve Common Housefly (CHF) puparia were used for both the zero-g and one-g sets of tests. The CHF puparia that were used

were "scheduled" to emerge shortly after launch, prior to observation in space.

Worker Honeybee (WHB) adults were raised in a special "nursery hive" environment and were from a colony that was certified to be free from disease. The bees were about six days old at the time of the STS-3 launch.

For all three species of insects used, the suppliers provided multiple shipments of insects, spread over time, to ensure that insects (adults, pupae and puparia) of the proper ages were available for use in the event of a postponement of the STS-3 launch.

The distribution of species and the number of insects loaded into Chambers A and B of the flight box were dependent upon the volume of the chambers and the food available to sustain the insects for the planned seven-day Shuttle mission. Also, for comparative reasons, the moths emerging from pupae were separated from the adult moths by a screen divider. A nearly equal number of insects were present in the two separate chambers. Fly puparia and moth pupae were not placed in the same chamber together since they may not have emerged in zero gravity, which would have resulted in no data on flight activity from one half of the flight box.

The distribution of insects was:

Zero-g Box (Flown on STS-3)

Chamber A	Chamber B
12 CHF Puparia	14 WHB
12 Male VBC Adults	6 Male VBC Pupae (glued down)*
12 Female VBC Adults	6 Male VBC Pupae (free)
	6 Female VBC Pupae (glued down)*
	6 Female VBC Pupae (free)

One-g Box (Used for control tests at Johnson Space Center)

Chamber A	Chamber B
12 CHF Puparia	12 WHB
12 Male VBC Adults	12 Male VBC Pupae** (all free)
12 Female VBC Adults	12 Female VBC Pupae** (all free)

*NASA approved "EPOXI-PATCH 608 CLEAR" epoxy was used to glue pupae to screen.

**NOTE: Apparently two empty pupal cases (rather than live VBC pupae) were accidently loaded into Chamber B of the One-g Box at JSC. Hence, the total number of live pupae in this Chamber was 22 rather than 24.

By providing pupae of moths (that emerged as adults in zero gravity prior to data collection) and adult moths (that had emerged prior to the flight) the flight activity of a group of younger adult moths that had never flown in one-g could be compared to older adult moths that previously emerged and had flown under one gravity. The use of moth pupae (and fly puparia) also provided information as to how successfully the moths (and flies) could emerge under zero-g conditions. In the zero-g box, half of the moth pupae were "glued down" on screen material to help ensure that at least some moth emergence would occur. Initially, there was some question as to how successfully they could emerge from their pupal cases while free-floating in zero-g.

Twelve hours prior to the scheduled launch time of STS-3, the insects were loaded into the insect flight box at the Kennedy Space Center. The same loading procedures were followed for the control group of insects at the Johnson Space Center.

The final preparation of the flight box for launch began by first removing the two screened end pieces to allow access to the feeders. Next, 12 moth pupae were glued to two small pieces of screen using the NASA approved epoxy glue. These pieces of screen were then attached to the inside of the screened portion of the end piece of Chamber B. The teflon feeders were removed and filled with approximately one fluid ounce of a sugar/water solution prepared by adding 6 teaspoons of "Perky-Pet Instant Nectar" granules to one cup of water. The two feeders were

re-installed on the inside of the back plane of the flight box. The two digital timers located in the box were checked for the proper time and date and the two screened end pieces were re-attached to close the flight box ends. Then, the adults, free pupae, and puparia of the three species were placed into the flight box, through the one inch diameter access holes located at the top of the box (Figure 1) and the access holes were sealed.

The flight box was placed into a stowage locker tray and the box and tray were then weighed on a scale. Their combined weight was 6 lbs., 14 ozs. (the insect box itself weighed about 4.5 lbs.). Two layers of plastic were secured around the box and tray for transportation to the launch pad. The experiment was stowed aboard the Space Shuttle Columbia in Mid-Deck stowage locker number MA9L.

STS-3 launch occurred at 10:00 AM. CST on March 22, 1982. At the time of launch at Kennedy Space Center (KSC), the one-g control box (with insects inside) was spun in a centerfuge at Johnson Space Center (JSC) to simulate the extent and duration of the acceleration forces exerted upon the space experiment during launch. This was done to avoid differences in the flight activity between the zero-g and one-g test insects that may have been caused merely by differences in pre-test acceleration levels present in the space experiment during launch. Figure 4 presents plots of the simulated g-profile (provided at JSC) and the expected nominal g-profile for the STS-3 launch/ascent

phase.

The STS-3 flight crew (Commander Jack R. Lousma and Pilot C. Gordon Fullerton) observed the insects and performed the collection of videotaped and photographic data in space. The author and JSC personnel observed the insects and performed data collection in the one-g environment at JSC. The following procedure (described in the STS-3 Photo/TV Checklist, reference 4 and the STS-3 Flight Requirements Document, reference 2) was used:

- Prepare video cameras, video tape recorder, and 35 mm camera to view and record the set-up and conduct of the experiment and to gather data.

- Remove the insect flight box from Mid-Deck stowage locker MA9L and install it on the airlock, above the airlock hatch.

- Obtain a minimum of 15 minutes of taped video and 5-10, 35 mm photographs of insect flight activity.

- Remove the insect flight box from the airlock and re-stow it in locker MA9L.

The Shuttle Orbiter landed at about 10:05 AM, CST on March 30, 1982 (192 hours after launch) at Northrup Strip, White Sands, New Mexico. The zero-g insect flight box was taken off the Shuttle Orbiter within one hour after landing and then transported, in an air-tight container, to the Johnson Space Center on a T-38 aircraft (in accordance with Space Shuttle

Program Requirements Control Board Directive No. S20757A, shown in Appendix A). It arrived at Johnson Space Center about eight hours after the Orbiter landing on March 30, 1982.

The next day (March 31, 1982), both the control and space experiment insect flight boxes were taken to the University of Houston, Biology Department to obtain post-experiment data on the condition of the insects. Table 1 provides a summary of the conditions of the insects observed and recorded at that time.

The flies were kept alive and observed at the University of Houston Department of Biology until their deaths. The moths were shipped to Dr. Norman C. Leppla at the USDA Insect Research Laboratory in Gainesville, Florida for post-flight examination and analysis. The 14 dead bees from the zero-g box were frozen for preservation. The 12 bees from the one-g box were given to Mr. Mel Coplin of Coplin Bee Farms.

Of the 14 dead bees from the zero-g box, seven were later given to Mr. Mel Coplin. Mr. Coplin later sent two of these (plus two of the dead bees from the one-g box) to Dr. H. Shimanuki at the USDA Bioenvironmental Bee Laboratory in Beltsville, Maryland for post-flight examination and analysis. Of the remaining seven bees from the zero-g box, three were later sent to scientists in the Biomedical Division at NASA's Ames Research Center at Moffett Field, California for electron microscope examinations of the physical condition of the bees' wings, legs and bodies (to assess the level of damage, if any, that

occurred during the STS-3 flight).

The results of the post-flight analyses, examinations, and observations of the insects that were performed at various laboratories are resented in the "Results" section of this report in the "Post-Flight Laboratory Observations" sub-section.

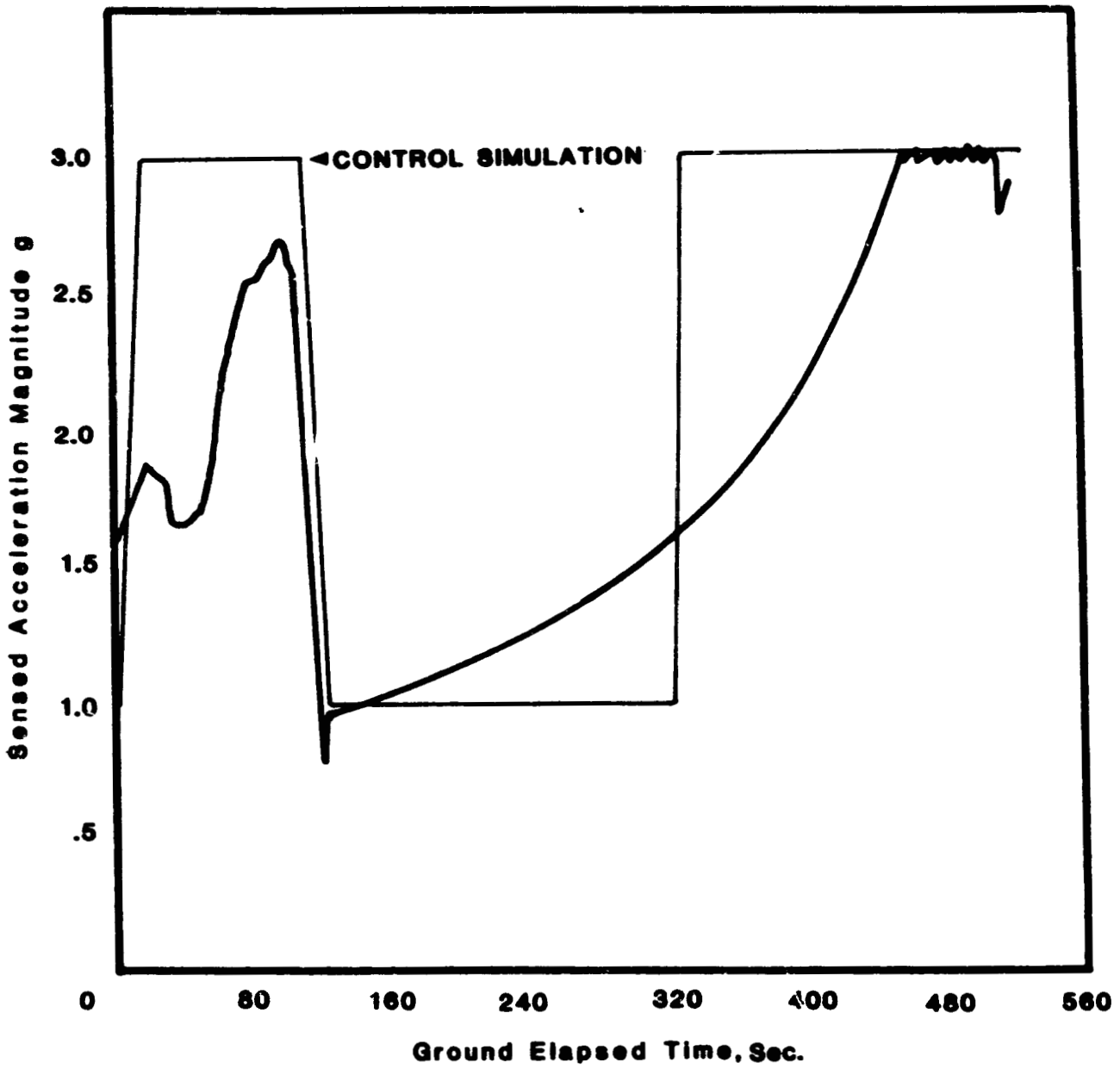


Fig. 4 Nominal ascent sensed acceleration compared to the control expr.

TABLE 1

CONDITIONS OF INSECTS AS OBSERVED AT THE DEPARTMENT OF BIOLOGY, UNIVERSITY OF HOUSTON ON MARCH 31, 1982

		CHAMBER A	CHAMBER B
ZERO-G BOX	NO. OF FLY PUPARIA EMERGED	10 OF 12	--
	NO. OF LIVE FLIES (ADULTS)	10 OF 10	--
	NO. OF MOTH PUPAE EMERGED	--	22 OF 24
	NO. OF LIVE MOTHS (ADULTS)	20 OF 24	15 OF 22
	NO. OF LIVE BEES (ADULTS)	--	0 OF 14
ONE-G BOX	NO. OF FLY PUPARIA EMERGED	12 OF 12	--
	NO. OF LIVE FLIES (ADULTS)	12 OF 12	--
	NO. OF MOTH PUPAE EMERGED	--	11 OF 22*
	NO. OF LIVE MOTHS (ADULTS)	16 OF 24	6 OF 11
	NO. OF LIVE BEES (ADULTS)	--	5 OF 12

*IT APPEARS THAT TWO OF THE "PUPAE" LOADED INTO CHAMBER B OF THE ONE-G BOX AT JSC WERE, IN FACT, EMPTY PUPAL CASES. AS A RESULT, 22 (RATHER THAN THE PLANNED 24) MOTH PUPAE IN THAT CHAMBER WERE "LIVE" PUPAE.

RESULTS

Data Obtained from NASA

After the STS-3 flight, NASA provided the author with the following data items related to the experiment:

- Approximately 27 minutes of videotaped views of the insect flight box and insect flight activity from the combined zero-g tests and one-g tests. Of this, about 18 minutes of the zero-g tape and about two minutes of the one-g tape provided useful data regarding insect flight behavior. Because of this, the results discussed here deal primarily with zero-g test observations.

- Eight 35mm photographs (8 x 10 prints) taken during the zero-g tests (no photos were obtained from the one-g tests). Of the eight zero-g photos, five provided useful data regarding insect flight behavior.

- Flight Crew responses to questions submitted by the author and the Corporate Sponsor to be asked at the STS-3 Crew Debriefing on April 8, 1982. A total of 15 questions were submitted. Answers to four of these questions were obtained from the Crew Debriefing. The questions submitted, and the Crew responses obtained are presented in Appendix B.

Hypotheses

The overall results of the experiment that relate to the two stated hypotheses can be summarized as follows:

- Hypothesis I: "Insects will encounter problems in pitching orientation in zero-g conditions, depending upon the type of flight control mechanisms present in the species of insect observed."

There is a relationship between each insect's ability to control its pitch attitude during flight and the type of flight control mechanisms the insect has. The flight activity of the insects, as observed on video tape by the author, varied considerably in duration and in ability of the insects to control their motion in zero gravity.

The flight activity of the fly in zero-g was very brief in duration; usually less than one second for each fly and in one case about four seconds. The flies appeared to be capable of controlling their pitch attitude and flight path very well during flight throughout the observation period in space.

The "active" flight activity of the bees in zero-g was also very brief in duration and usually resulted in floating, without wingbeat, with no control of attitude in any axis. In one case, two bees were observed on the screen together. Both bees left the screen, "hooked" together and spinning rapidly, which lasted for about 25 seconds. After separating, both

bees went off spinning in different directions.

The flight activity of the moths in space was also brief, lasting less than ten seconds during each attempt by a moth. During flight, the body axis might be oriented in any direction. The moths' flight patterns were very uncontrolled and would often "level off" to just maintaining position against the surface of the flight chamber.

In summary, this hypothesis was supported by the results obtained. The flies (whose flight control mechanisms include halteres) did appear able to control their orientations and flight paths better than the moths or bees.

- Hypothesis II: "In the absence of gravity, flying insects will be attracted to, and fly in, the area of the brightest illumination in the flight box."

This hypothesis was difficult to confirm since neither direction of the light source nor intensity of lighting of the insect flight box were systematically varied as part of the experiment.

On the first test day in space (flight day 3), the lighting conditions were uniform throughout the flight box. The flight activity of all insects was also observed throughout the flight box, with no apparent preference for any area. The moths would often rest on the front plane of the box.

The lighting conditions were different during the second test

day in space (on flight day 6). The light intensity was greatest in the upper third of the flight chamber. All moths exhibiting flight activity did so in the region of the brightest illumination. However, without systematic variation of the lighting, the degree of attraction cannot be determined. On the second test day in space, no moths were seen resting on the front plane of the box.

The attraction towards light among the bees and flies cannot be determined at this point since the bees mostly floated about and the flies tended to fly in all areas of the box during both periods of observation in space.

In summary, this hypothesis was supported to some extent by the results for the moths but not for the bees and flies.

Other Observations

One relationship observed was that agitation (i.e., tapping, shaking, rotating, etc.) of the flight box by the astronauts caused an increase in flight activity for all three insect species. One instance of this occurred when one of the astronauts bumped the box when it was mounted on the airlock. Another instance was during astronaut manipulation, when the box was removed from the airlock. When the velcro pad hook and pile surfaces were pulled apart, which normally causes some vibrations (and a "ripping" sound), again the flight activity increased (most notably in the moths). Figure 5 shows the increase in flight activity of the moths in response to two

vibrations of the box by the astronauts.

Insects greatly stimulated one another to fly throughout the observation in space. This was largely caused by the moths and the bees inability to control their direction of travel when in flight and their resultant collisions (or near collisions) with other, "resting", insects.

Also, air disturbances (created by the moths and bees especially) would stimulate additional flight among all three species of the insects when they were at rest in zero gravity.

Emergence of both fly puparia and moth pupae in space was successful. Post-flight analysis, as shown in Table 1, indicated that 10 of the 12 fly puparia and 22 of the 24 moth pupae emerged during the STS-3 flight. A large number had emerged prior to the first observation (at about 55 hours after the launch of the Space Shuttle on flight day 3). This observation is supported by videotaped data and 35 mm photos taken at that time. Eighteen adult moths were counted in Chamber B in one photo. Since 12 pupae were glued down and 12 pupae were freely floating in Chamber B, there must have been little difference in the moths ability to emerge from pupae that were either glued down or freely floating in space.

No major differences in flight activity were observed between the younger adult moths which emerged from pupae and developed their wings in zero-g and the older adult moths that had

emerged on Earth.

A moth in zero-g having difficulty making firm contact with a surface responded by briefly flapping its wings until contact was complete. The legs and feet of the moth could then be used for anchorage. Most moths in one-g preferred to stay on the bottom or floor of the flight box, perhaps due to energy expended overcoming gravity when flying.

Moths in Chamber B ("young adult" moths) of the zero-g box were occasionally seen floating with the wings flat open. No more than a single moth was ever seen floating at any given moment during observation. No moths in Chamber A ("old adult" moths) of the zero-g box were observed to float at any time in space. A typical float period started with a moth flying and then stopping its wingbeat to float and then later resuming wingbeat. The duration of floating increased during the first (flight day 3) observations in space. Ten separate periods of floating behavior were noted during these observations. Nine of these periods lasted 5-25 seconds. The greatest period observed in space was nearly three minutes long. However, on flight day 6 in space, two moths were seen floating throughout the testing. Since no wingbeat was seen for these moths, they may have been dead. Also, their wings were closed compared to wings fully opened during floating behavior observed on flight day 3.

In the one-g control tests, the moths never flew head down or upside down. Changes in velocity during zero-g flight occurred

as a result of a pause or reduction in amplitude of the wingbeat, leading to variable pitching rotation and loss of speed. As the moth again began to best its wings more strongly, it might move off in a different direction determined by the new pitch angle.

Five 35 mm photographs were analyzed to determine the orientation of the long body axis of moths on the front plane in zero gravity. Results are shown in Table 2. An interesting feature of the behavior of moths at zero-g, both while at rest and in flight, was that the long axis of the body might be oriented in any direction with respect to the box frame of reference. The body axis when at rest seemed to be solely determined by the direction of flight prior to landing on a surface.

The flies observed in space spent more time walking about in random directions than flying. A group of six flies walking on the front plane could be seen briefly flying a few inches at a time. No floating occurred for any flies during any time of the observation. The flies legs and feet enabled them to cling to all interior surfaces of the flight box.

The bees in space preferred to stay on the screened surfaces. At one time, seven bees could be seen walking on the screened central divider. A similar response occurred in both the zero-g and one-g tests when a bee was observed walking on the screen surface until coming in contact with the smooth Lexan surface.

An immediate response to fly was then observed. One bee was observed flying against the front Lexan surface, gradually changing his direction of motion until he came into contact with the screen. He then grasped the screen, ceased wingbeat, and rested.

When a bee was floating in space, its legs would be moving (as observed in the video data and confirmed by the astronauts). More bees were seen to be floating on flight day 6 than on flight day 3. This may be a result of an increase in the number of dead bees observed on flight day 6.

A photograph of the flight chamber from space reveals the feces deposits on the inner surfaces of the box. Marks left by bees and moths were the most noticeable. Patterns of feces distribution in the zero-g box differed greatly from those in the one-g box. In the one-g box, the moths feces covered an area around the perimeter of the box, with the heaviest coverage by the feeder. In the zero-g box, an even coverage of feces was present throughout the box.

Post-Flight Laboratory Observations

The results of the post-flight observations of the insects at various laboratories (that were mentioned earlier at the end of the "Procedures" section) are summarized below. For reference, Table 1 presents the counts of the numbers of insects in the zero-g and one-g flight boxes when they were initially examined at the University of Houston Biology Department on March 31,

1982 (the day after the STS-3 landing).

In an informal communication, Dr. Rick Lee (who is now at Miami University in Hamilton, Ohio) provided the information presented in Table 3 for the flies that were retained and observed at the University of Houston. The data in Table 3 indicates a decrease in the reproductive performance for the female flies that flew on the Space Shuttle as compared to those that remained in the normal one-g environment. These observations (and others) will be the subjects of a future paper (now in preparation) by Dr. Lee, Dr. Edwin Bryant, and Dr. John Baust.

In other informal communications, Mr. Mel Coplin and Dr. Rick Lee provided the results of an analysis of the sugar content of the remaining sugar-water solution in one of the insect feeders from the zero-g box. This analysis was performed at the University of Houston (using high performance liquid chromatography) on March 31, 1982. The sugar content found in the solution was:

Sucrose	12.1%
Fructose	0.9%
Glucose	8.0%
TOTAL	21.0%

In other informal communications, Dr. Delbert Philpott and Dr. Jaime Miquel of NASA's Ames Research Center provided the results of electron microscope examination of three of the bees

that flew on STS-3. This work was carried on at NASA/Ames and may also result in a subsequent paper or report by Ames scientists. In summary, no damage to the bees' wings, legs, or bodies was observed.

In addition, Dr. Shim Shimanuki of the USDA Bioenvironmental Bee Lab in Beltsville, Maryland provided the following summary from his examination of the four bees (2 from the zero-g box and 2 from the one-g box) sent to him by Mr. Mel Coplin:

- The zero-g bees were free of any known bee diseases
- Clipping of the tips of the bees' stingers did not reduce the lifespan of the bees
- The sugar solution used for feeding the insects was "too dilute" to sustain the bees over a 9-day period
- The use of epoxy glue (to glue moth pupae down in Chamber B of the zero-g box) did not seem to harm the bees
- The problem of bee survival was probably with the sugar solution and feeding system (i.e., the bees could not get sufficient food).

Dr. Norman C. Leppla of the USDA Insect Research Laboratory in Gainesville, Florida provided information based upon his post-flight observations of the moths used in the experiment and the progeny of these moths. Dr. Leppla's observations will also be the subject of a subsequent paper or journal article.

In summary, the observations indicated:

- The VBC moths that flew on STS-3 did not mate while in the zero-g environment. They did mate after being returned to the laboratory and showed no appreciable decrease in fertility as compared to the one-g control group of moths observed at JSC.

- The rate of oviposition and the development of resulting progeny was equivalent for the two groups for two generations of the moths in the laboratory.

- Table 4 presents a summary of the longevity of the moths following the STS-3 flight (and return of the moths to Dr. Leppla's laboratory). Figure 6 presents plots of the data in Table 4 (Note: In Figure 6, Day 10 is March 31, 1982).

Fig. 5 The Result of Astronaut Induced Vibrations on Flight Activity of Moths in Space

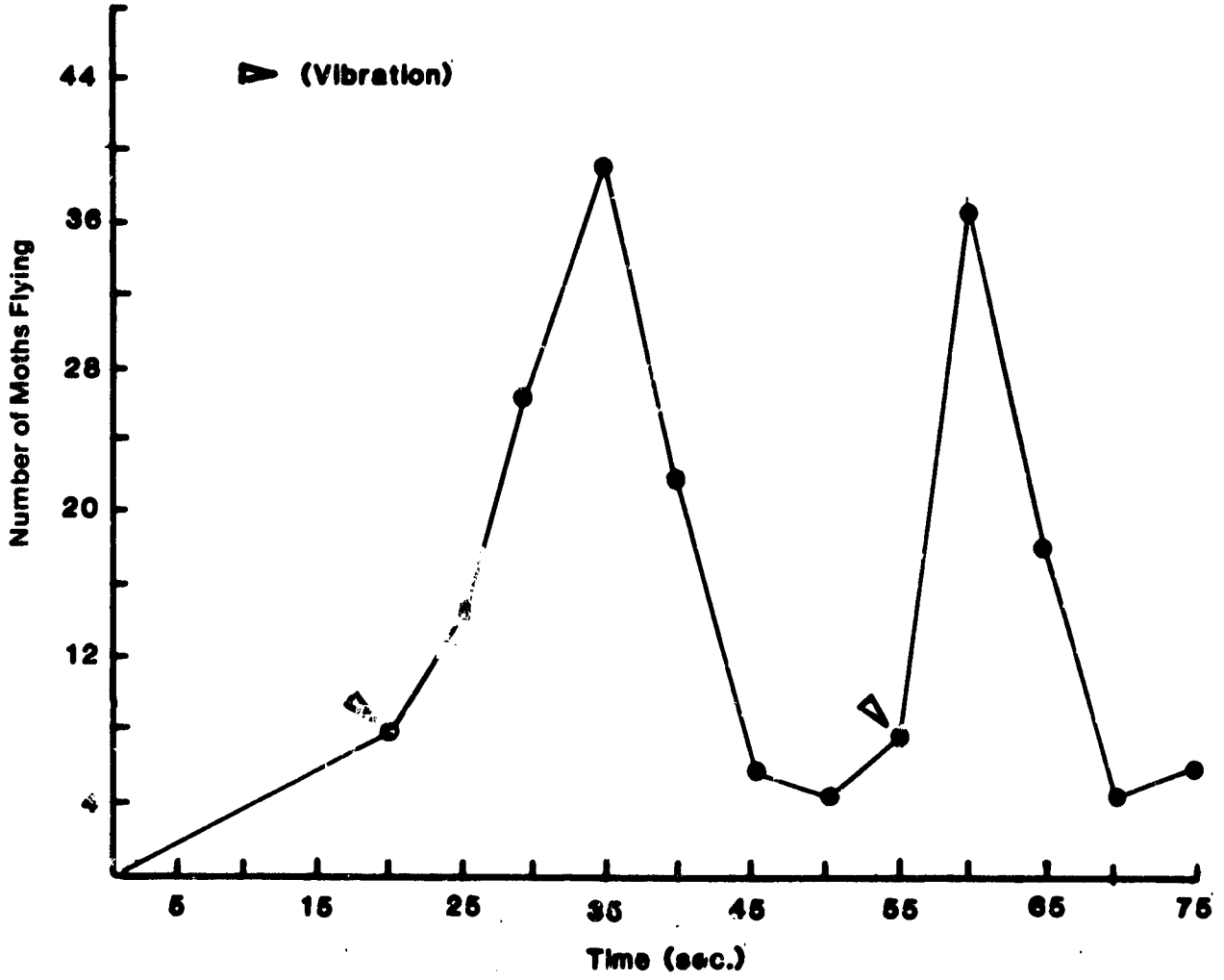


TABLE 2

NUMBERS OF MOTHS AT VARIOUS BODY ORIENTATIONS ON THE FRONT PLANE OF THE INSECT FLIGHT BOX

GRAVITY LEVEL (2)	BODY ORIENTATION (1)			
	HEAD UP	HEAD DOWN	HEAD RIGHT	HEAD LEFT
ZERO-G	17	20	18	3
ONE-G	8	0	0	0

NOTES:

(1) FOR BODY ORIENTATION:

- "HEAD UP" INDICATES BODY AXIS $>30°$ ABOVE HORIZONTAL
- "HEAD DOWN" INDICATES BODY AXIS $>30°$ BELOW HORIZONTAL
- "HEAD RIGHT" AND "HEAD LEFT" INDICATES BODY AXIS $\leq 30°$ FROM HORIZONTAL

(2) THE DATA WERE OBTAINED AS FOLLOWS:

- FOR ZERO-G: COUNTING NUMBER OF MOTHS AT EACH ORIENTATION IN 5 PHOTOS TAKEN DURING ZERO-G TESTS. COUNTS ARE SUMS FOR THE 5 PHOTOS.
- FOR ONE-G: COUNTING NUMBER OF MOTHS AT EACH ORIENTATION DURING A ONE-MINUTE VIEWING OF VIDEOTAPE FROM THE ZERO-G TESTS.

TABLE 3

POST-FLIGHT OBSERVATIONS OF FLIES AT THE UNIVERSITY OF HOUSTON

		ONE-G BOX	ZERO-G BOX	ZERO-G BOX VS. ONE-G BOX
PERCENT OF FEMALES LAYING EGGS AT FIRST OPPORTUNITY (N=7 FOR EACH BOX)		85.7%	28.6%	-57.1%
NUMBER OF EGG CLUTCHES LAID PER FEMALE OVER THE LIVES OF THE FEMALES $\bar{X}$ ± SEM*		6.2 ± 0.7	4.5 ± 1.3	-27.4%
TOTAL NO. OF EGGS LAID PER FEMALE DURING FIRST 35 DAYS $\bar{X}$ ± SEM		531.6 ± 50.3	390.5 ± 99.9	-26.5%
LONGEVITY (DAY 1 = 3/23/82) $\bar{X}$ ± SEM (RANGE)	FEMALES	34.4 ± 2.6 DAYS (28 - 43)	34.2 ± 4.3 DAYS (23 - 45)	-0.6%
	MALE	17.6 ± 2.6 DAYS (11 - 25)	26.0 ± 2.0 DAYS (22 - 28)	+47.7%

*$\bar{X}$ = MEAN, SEM = STANDARD ERROR OF THE MEAN (STD. DEV. ÷ $\sqrt{N}$).

TABLE 4

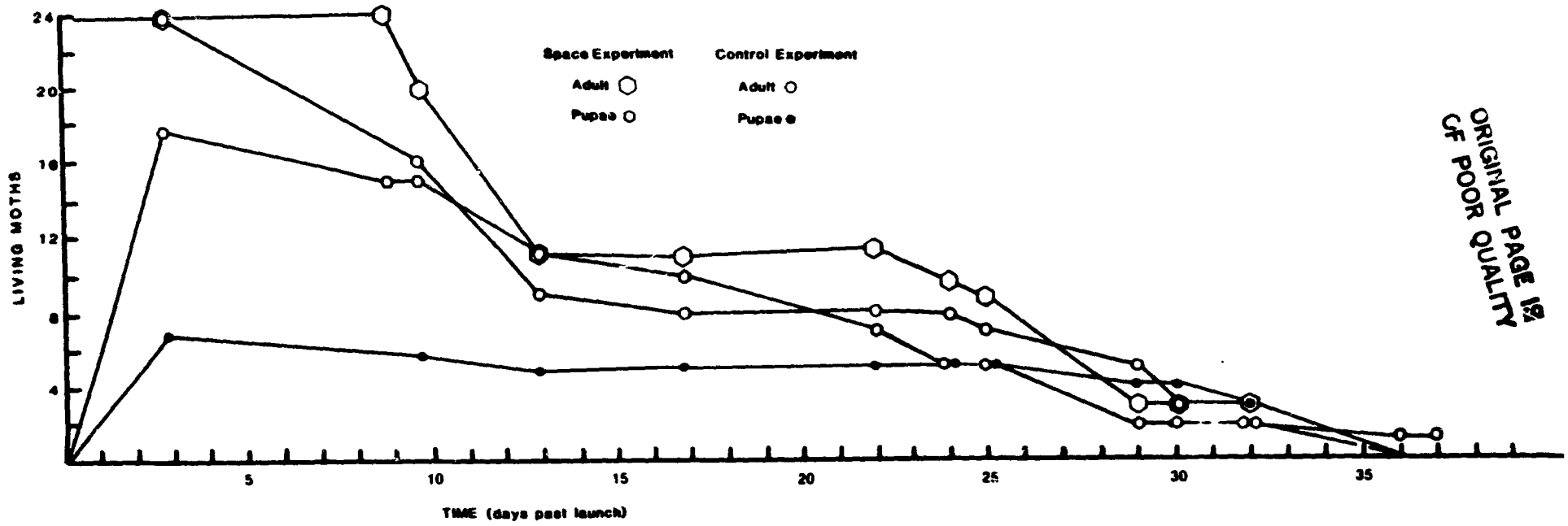
NUMBER OF LIVE MOTHS ON GIVEN DATES
(AT THE USDA INSECT RESEARCH LAB IN GAINESVILLE, FLORIDA)

		DATE*											
BOX	CHAMBER	3/21	3/31	4/2	4/7	4/12	4/14	4/15	4/19	4/20	4/22	4/26	4/27
ZERO-G	A	24	20	11	11	11	10	9	3	3	3	0	0
	B	24	15	10	10	7	5	5	2	2	2	0	0
ONE-G	A	24	16	9	8	8	8	7	5	3	2	1	1
	B	22	6	5	5	5	5	5	4	4	3	0	0

*REFERENCE DATES

3/21/82: MOTHS LOADED INTO FLIGHT BOXES (AS PUPAE IN CHAMBERS B)
3/22/82: STS-3 LAUNCH
3/30/82: STS-3 LANDING
3/31/82: FIRST POST-FLIGHT COUNT OF INSECTS (AT UNIVERSITY OF HOUSTON)
4/2/82: REMAINING LIVE MOTHS RECEIVED AT USDA LAB IN GAINESVILLE, FLORIDA
4/28/82: LAST REMAINING MOTH (MALE FROM CHAMBER A OF ONE-G BOX) WAS "TERMINATED"

Fig. 8 LONGEVITY OF VELVET BEAN CATERPILLAR MOTH



DISCUSSION

Conduct of this experiment aboard a Space Shuttle flight enabled study of the activity of insects at zero-g for a longer time period than previously has been possible. The STS-3 flight was an eight-day mission in space for 74 "insectronauts". The experiment was stowed in darkness in a stowage locker, with air circulation present, for nearly the entire mission, except for the approximately 30 minutes of exposure to light during data collection. This may have modified the overall natural responses of the insects when initially exposed to light for the data collection.

It would have been desirable to observe the insects' reactions during their very first exposure to weightlessness after launch. However, an automated data collection system would have been needed for this initial observation in space, since no crew involvement could be expected at such a critical phase in the mission.

Species were carried together in the flight box. Perhaps the presence of other insect species also resulted in modified responses. Insects may have reacted differently if each species were alone in the flight box.

Other artificial stimuli were the vibrations induced by the astronauts' manipulation of the box. The moths, which responded the greatest during vibration, may have not even attempted to fly at all during observation had the astronauts not

manipulated the box (by tapping, shaking, and rotating it).

The flight box itself represented an obviously artificial situation for all of the insects flight activity, since it constrained their flight to a relatively small area.

The textures of the inner surfaces varied from screen to smooth Lexan plastic. Since the three species studied have structurally different feet and legs, their ability to cling to any surface was not the same. This may have had an effect on the location of an insect when at rest since, in space, clinging to a surface was necessary to serve as an "anchor" to prevent drifting when not flying.

Of the insects observed, the bees seemed to be limited to the greatest extent. The bees were observed resting and walking only on the screen surfaces of the box in zero gravity. The bees also appeared to experience great difficulty in controlling their orientations for landing and for properly contacting a surface to grasp it prior to a rest period. Only one bee was ever observed to land on a smooth Lexan surface in zero-g. This bee then flew again, soon afterwards, upon being contacted by a moth. Bees in the control (one-g) tests, however, were capable of landing on Lexan. The bees in zero-g were probably not able to make the proper contact for grasping the Lexan due to their unstable flight patterns. During the zero-g tests, bees were often seen floating and spinning about their center of mass. This indicates that the resultant of the

total aerodynamic forces did not pass through the center of mass. Measurements of the stroke angle and wingbeat amplitude at zero-gravity would be of value. In space, the tendancy for a bee to continue to float may be due to lack of further stimuli necessary to continue the flight activity (e.g., "expected" motion of the visual field, sensation of relative wind on their bodies, etc. that usually accompanies flight). Bees in zero-g were observed flying into Lexan, continuing bodily contact with the Lexan, but apparently unable to cling to it. Both in the one-g and zero-g tests, when a bee was seen walking from a screen surface to a smoother Lexan surface, the response to contact with the Lexan was immediate flight.

Moths in zero-g also appeared to have some difficulty orienting themselves for landing on a surface of the box. This difficulty in landing orientation was probably due to the random orientation of the moths' body axes during flight. Normally, under one-g, the moth will maintain its long body axis at an angle which allows its prolegs (which act as buffers for landing) to contact the surface. In the zero-g tests, this degree of control appeared to be absent. Moths on flight day six experienced "unexpected" drifting in attempting to land on a surface when they failed to make good initial contact with it. This may have then caused floating responses.

Flight of an insect in one-g requires development of a force to counteract gravity. An insect is propelled in a direction and at a velocity determined by the resultant of three forces:

1) reaction to thrust generated by wingbeats, 2) resistance offered by the air to the passage of the insect through it (drag), and 3) the downward pull of gravity.

In space, the downward pull of a gravity is absent, and insect flight velocities will increase unless the insect reduces its aerodynamic output (frequency and/or amplitude of wingbeat). Moths may have encountered difficulties in controlling their flight due to unexpected increases in flight velocity with "normal" wingbeat output. May, et al (1980) state: "As the period of 0g continued, moths were increasingly likely to periodically reduce the amplitude of their wingbeat and/or stop flying, for the equivalent of a few wingbeats. Only at 0g, moths very occasionally spread their wings and floated freely for a few seconds." Perhaps an adaptation may result over time in the form of reduced aerodynamic output. If so, measurement of wing beat and flight velocities over a more extended period would tell so.

On the sensory side, flight is initiated in most insects by a loss of contact by the feet with some surface. In zero-g, an insect will float after loss of contact with a surface unless wingbeat activity is resumed.

Flies were able to orient their bodies properly for landing upon any surface in the box. The flies were not limited to landing and resting on any single surface, due to the ability inherent in their feet to cling to any of the surfaces

provided. No floating was observed among the flies. This may be so because of the fly's adaptability to the environment to which it was exposed and because they have halteres (which apparently act as gyroscopes that provide flight stability for the fly).

The real problem faced among insects in space is flight control during locomotion and, as observed, the flies, bees, and moths accomplished this by different combinations of flying, floating, and walking on a surface.

The insects in space were provided with a feeder, in each chamber, having a circular surface area of 0.375 inch in diameter. The problem of dispensing a liquid in space that all the insects can use as food is perhaps unnecessary. Rather, several separate types of food should probably be provided to meet the individual needs of each species. A sugar solution is not the best food for young bees removed from a colony.

The chances of the bees getting to the feeder were reduced in zero gravity, since they were not flying well and could not easily walk to the feeder which was located away from the screen. It is also possible that the sugar solution may have granulated in space, stopping or reducing the flow of liquid to the exposed surface of the feeder wick. Bees will not live without food. The most likely reason for death among all 14 bees was a lack of food in space.

Both moth pupae and fly puparia emerged in space. Twenty-two of

the 24 moth pupae and 10 of the 12 fly puparia in the zero-g space experiment emerged during the flight. The use of pupae, which will emerge as adults in space at a specific time for observation, turned out to be practical since there were no problems in emergence and wing formation in zero gravity for the fly puparia or the moth pupae. Also, by providing pupae of insects, an additional assurance of surviving the launch accelerations (3-g's maximum) is provided by the inherent protection provided by the pupal casing.

When storage volume is critical, by using pupae of insects, the amount of space food required and the build-up of feces in the experiment box are also reduced.

CONCLUSIONS

The results from this insect flight motion study may have raised more questions than they have answered. This has opened up new and exciting areas for future research, which can add to what is already known about insect motion in zero-gravity.

Some things were learned from this experiment with regard to the design of insect habitats for use in the zero-g environment of space. The design of such a habitat should provide such things as:

- A food/water source that can be easily accessed by, and that will provide for the nutritional needs of, each of the insect species to be carried. The food/water material should be "confined" to prevent floating particles from interfering with normal activities.

- Textures of materials inside the habitat that will allow all species of the insects to easily maintain resting positions on (or move about on) the surfaces in zero-g. The nature of the insects' feet must be considered in the selection of these materials.

- Suitable environmental conditions (of lighting, temperature, humidity, volume, air pressure, oxygen, etc.) to maintain the various species to be housed in the habitat.

- Some waste collection system to prevent floating debris

and deposits on surfaces (especially if clear viewing and/or recording of insect activity is required).

The difficulties encountered by the insects in zero-g in this experiment appeared to include: reduced control of body attitudes and flight, failure to adjust aerodynamic outputs for zero-g conditions, failure to orient their bodies for proper landings on surfaces, inability to cling to some surfaces, failure to maintain wingbeat after loss of contact with a surface (which led to floating), accessing the food/water source, and (possibly) mating. Some of these difficulties could have been avoided by modification of the design of the insect habitat that was used (including the feeder system and food material used). Others were apparently caused by the effects of weightlessness itself.

Other results of interest from this experiment include:

- The three species of insects used in this experiment apparently were not harmed by the launch/ascent accelerations, the zero-g conditions, or the re-entry and landing accelerations that occur in Space Shuttle flights. Presumably, this would also be true for a number of other species.

- Zero-g conditions are compatible with emergence of insects from pupal stages, whether "glued down" or free floating (at least for the moths and flies used in this

experiment).

- Data collection for experiments of this type can be improved by obtaining more close-up recorded views of the insects in flight and the use of fixed camera locations, orientations, and fields of view.

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  - Support to the final definition of the experiment (selection of insect species, selection of food/water sources for insects, definition of test procedures to be used, definition of data recording requirement, etc.)

  - Design and build of the Insect Flight Boxes

  - Contact and coordination with entomologists to provide

insects, consultation and advice

- Coordination with NASA to obtain approval of the experiment, procedures, apparatus, schedule, etc.

- Providing for trips by the author to various locations (e.g., Honeywell Avionics Division in Florida, JSC, KSC, etc. and the trip for the author, his parents, his science teacher, and others to KSC for STS-3 launch)

- Support in preparation of this report

- Just being "such great guys to work with".

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2. NASA Document No. JSC-10783, STS-3 Flight Requirements Document, Final; 15 January, 1982 (through Change No. 3).

3. NASA Document No. JSC-17472, Space Shuttle Student Experiment Integration Guide, (no date).

4. NASA Document No. JSC-17626, STS-3 Photo/TV Checklist, Final; 11 January, 1982 (through Page Change Notice No. 2; 10 March, 1982).

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APPENDIX A

Space Shuttle

Program Requirements Control Board

Directive No. S20757A

PCIN 20757	SPACE SHUTTLE PROGRAM REQUIREMENTS CONTROL BOARD DIRECTIVE - LEVEL II	PAGE 1 OF 2
PRCBD S20757A		PRCB DATE #

CHANGE TITLE
REMOVE STUDENT EXPERIMENT FROM ORBITER AT LANDING SITE

CHANGE PROPOSAL(S) NO. AND SOURCE	DOCUMENTS AFFECTED (NO.,TITLE,PARA)
LEVEL II CHANGE REQUEST S20757A PRCBD S20757	JSC-08241-003 V072-300001 JSC-17768-003
INITIATED BY: JSC-EW/J. JACKSON	SUBMITTED BY: JSC-LA3/R. MACHELL

LEVEL II BASELINE CHANGE DIRECTION: OPR: LA2 JS/BFM

THIS PRCBD IS ISSUED TO AUTHORIZE THE FOLLOWING CHANGE:

. PROVIDE FOR THE REMOVAL OF THE COMPLETE STUDENT EXPERIMENT (BEES AND
. MOTHS) FROM LOCKER MA9L AT NORTHRUP STRIP AND RETURN TO JSC VIA T-38
. AIRCRAFT OR EARLIEST AVAILABLE COMMERCIAL FLIGHT.

EFFECTIVITY: STS-3

LEVEL II IMPACTS AUTHORIZED BY THIS DIRECTION --COST: NONE,
--SCHEDULE: NONE, --WEIGHT: NONE.

ACTIONS:

KSC-SP: (1-1)	IMPLEMENT THIS CHANGE IN YOUR PROJECT.	
.	ACTION DUE: MARCH 29, 1982.	
.	CATEGORY I	
JSC-LB: (2-1)	IMPLEMENT THIS CHANGE IN YOUR PROJECT.	
.	ACTION DUE: MARCH 29, 1982.	
.	CATEGORY I	
JSC-LB: (3-1)	REVISE THE FLIGHT MANIFEST, JSC-08241-003 TO REFLECT THIS CHANGE.	
.	ACTION DUE: MARCH 29, 1982.	
.	CATEGORY I	

THIS PRCBD WAS PROCESSED OUTSIDE THE FORMAL LEVEL II PRCB.

AUTHORIZATION:		CLOSE-OUT DOCUMENTATION (ENTERED BY LEVEL II PRCB SEC)
/S/G. S. LUNNEY	03/25/82	
CHAIRMAN, LEVEL II PRCB	DATE	

APPENDIX B

Questions Submitted for the

STS-3 Crew Debriefing on

April 8, 1982

and Crew Responses

Questions submitted for the Todd Nelson's Student Experiment on STS-3

1. was the insect box easy to handle?

2. When you first removed the box what kind of insect activity did you observe?

3. How much video did you take?

4. How many 35mm shots did you take?

5. How much time did you observe the insects that was not recorded on TV or photographed?

6. What proportion of each species was alive at the time of the two tests?

7. What is the number of both the free and attached pupae in Chamber B that emerged?

8. Of the new emerged moths in Chamber B what was the condition of their wings (well formed or misshapen)?

9. Did you note any "bad" interactions between the moths and bees in Chamber B (agressive or bumping during flight)?

10. Did you see any insects that were, or appeared to be, dead but were moved by other insects?

11. How well coordinated were the insects when walking or landing?

12. Was it comforting to have some other living animals aboard beside yourselves?

13. How would you describe the flight behavior of the insects (bees, moths, and flies)?

14. What could be done to improve the experiment in your opinion?

15. How many bees were alive when you last observed them?

Responses of the STS-3 Crew

To Questions About the Student Experiment --

Insect Motion Study

1. Q. Was the insect box easy to handle?

   A. They indicated that it was very well constructed for the required use and data gathering.

5. Q. How much time did you observe the insects that was not recorded on TV or photographed?

   A. It was indicated that the experiment was taken out of the locker twice. The first time was scheduled in the CAP the second time was not. Both TV and pictures were taken.

13. Q. How would you describe the flight behavior of the insects. (bees, moths and flies)?

   A. The bees did not flap their wings. They just floated around in the box kicking their feet. The moths flapped their wings but would bump into the walls of the box. The flies just crawled around.

14. Q. What could be done to improve the experiment in your opinion?

   A. Gordon Fullerton was very direct in saying that the contents of the experiment box was not as it was defined to him preflight. He indicated that no one

had mentioned that flies would be part of the experiment. He also indicated that he thought the bees and the moths would be in separate compartments of the box but instead they were all mixed up. It was suggested by both crew members that a written description of the experiment be supplied to them preflight. Suggested that no changes be made to the experiment without notification of the crew.

COMMENT

Crew appreciated the experiment it was fun - not so serious.

APPENDIX C

Photographs Available from NASA of

Insect Flight Observation

NASA Headquarters

Photo No.	82-HC-232 (color) 82-H-251 (b & w)	Onboard, Jack Lousma with flight chamber
	82-HC-259 82-H-266	Closeup view of flight chamber
	82-HC-218 82-H-224	JSC Mission Operations Control Room with television transmission of experiment

NASA/JSC

Photo No.	STS-3-23-173 (color)	Onboard, Jack Lousma with flight chamber
	STS-3-23-175	Closeup of flight chamber
	STS-3-23-176	Closeup of flight chamber
	S-82-31197	Empty flight chamber after flight