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THE BIOSATELLITE PROGRAM

by
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ABSTRACT

THE BIOSATELLITE PROGRAM

Successful manned spaceflights to date have proved that at least for brief periods, the human organism can indeed survive and function in the hostile environment of space. But, many unanswered questions still remain regarding the physiological and behavioral effects of prolonged space travel on man's overall performance and viability.

Reports by the United States and Russia have indicated that even after only five days in space, astronauts have experienced changes in their circulatory systems, also in the biochemical characteristics of their blood and urine. These changes point to the vital need for the extensive investigation of biological processes under controlled space conditions.

NASA's Biosatellite, managed by Ames Research Center, under development by General Electric's Re-entry and Environmental Systems Division is an orbital spacecraft and re-entry system designed specifically for this purpose. Biosatellite experiments are aimed at studying the effects of long-term weightlessness, and weightlessness combined with radiation, as well as the removal of biological specimens from the direct influence of earth's periodicity.

The Biosatellite is a fully automated system, featuring provisions for a sea level atmosphere, control of gravitational forces in orbit to less than 10^{-5} earth gravity, and extensive command, telemetry and on-board tape and film recording. Recovery from orbital flight of all experiments allows post-flight analyses and evaluation by the Bio-sciences community.

Biosatellite missions are categorized by their nominal time in orbit, with experiment objectives as follows: the purpose of the 3-day mission is to determine the effects of weightlessness and possible interaction between weightlessness and ionizing radiation on low order plant and animal life; the purpose of the 30-day flight is the study of neurophysiological, cardiovascular, and metabolic functions in a high order primate.

Both 3-day and 30-day mission systems have been successfully flown and their recoverable capsules returned. Although the primate experiment was terminated after nine days of orbital flight due to ~~primate behavioral anomalies~~, the space support module of the system has been operated in orbit for over 30 days. NASA has obtained valuable performance and reliability data for future missions by exercising the space support module in this post-experiment phase.

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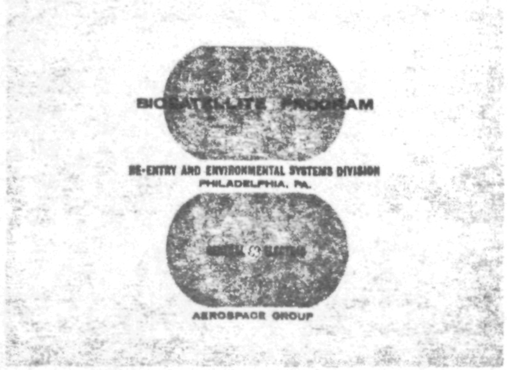

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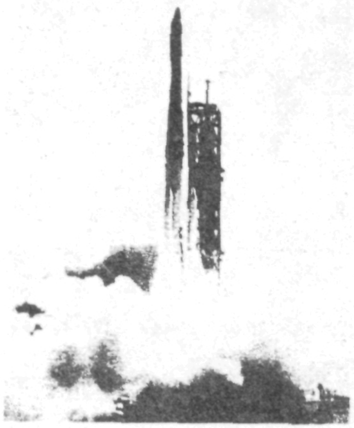
THE BIOSATELLITE PROGRAM

SLIDE 1 BIOSATELLITE PROGRAM

The Biosatellite Program is the first United States space orbital, re-entry recovery system developed for the purpose of investigating basic biological phenomena, among which are the fundamental effects of the unique factors of space environment on living biological systems. Biosatellite experiments were designed to study the effects of long-duration space flights, lasting three and thirty days, on a wide variety of biological specimens, in a closely controlled environment that cannot be duplicated on earth. The effects of weightlessness, with and without radiation, and the effects of removal from the direct influence of the earth's periodicity are being investigated.

SLIDE 2 THE BIOSATELLITE TEAM

The Biosatellite Program represents a fine example of the cooperation possible between the government, scientific community, and industry. The Ames Research Center of our National Aeronautics and Space Administration, located at Moffett Field, California, provides overall management and technical direction to the program. The scientific community suggested over 200 different experiments to be flown aboard the Biosatellites. From these, NASA, in conjunction with panels of leading scientists, selected 16 experiments which were felt to be most likely to reveal significant results. NASA Ames Research Center is responsible for the overall program management; General Electric is responsible for developing and building the orbiting system with its re-entry and space support modules, for designing and building some of the experiment hardware, and for integrating all experiment hardware into the spacecraft; various universities and institutions as shown on the slide provide the experimenter teams.



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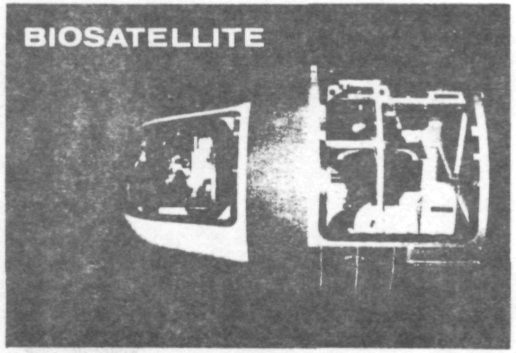
SLIDE 3 BIOSATELLITE I LAUNCH

As you may know, two 3-day missions and one 30-day mission have already been flown. Biosatellite I flew in December 1966 for 3 days, during which the on-orbit experimentation was successfully conducted. However, the recovery sequence could not be initiated, and the experiment specimens were not recovered. An identical 3-day configuration called Biosatellite II was launched in September 1967. Biosatellite II operated in orbit for two days and was successfully recovered with the experiments intact. . . a very satisfactory flight.

The 30-day mission, called Biosatellite III, was launched in late June 1969. After about eight days in orbit the physiological state of the primate became depressed and he ~~The primate was seen observed to be behaving abnormally and~~ was recovered in the capsule of the re-entry module ~~after nine days in orbit~~ on the ninth day. The space support module, planned to remain in orbit, continued to function within specification for the full 30 days.

I would like to discuss the Biosatellite system in general, the experiments, the hardware, the mission profile, and then briefly touch upon the significant results obtained from the Biosatellite II and III flights. Although Biosatellite III results are not yet fully available, preliminary data seem to indicate a severe shift in the circadian rhythm of the animal.



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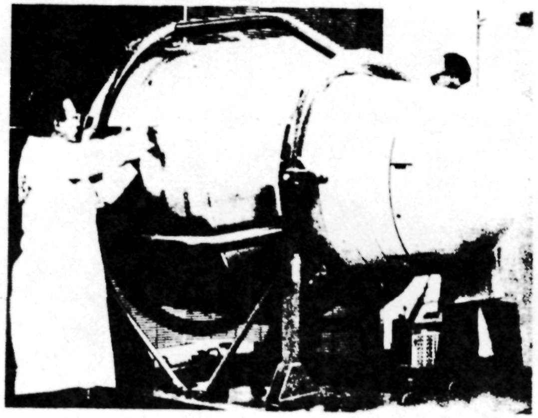
SLIDE 4 BIOSATELLITE SYSTEM

The Biosatellite system (which is shown here in its 30-day orbit configuration), is designed to permit study of the fundamental effects of the unique factors of the space environment on living biological systems. Among these are the effects of weightlessness combined with radiation, and the effects of removal from the direct influence of the earth's periodicity on the metabolic rhythms which are normally of a circadian (about 24-hour) nature under earth conditions. Living systems, exposed to simultaneous weightlessness and controlled radiation, were examined to find out whether these environmental factors are synergistic or antagonistic, or whether they are at all significant when compared to the control conditions of the earth environment.

The Biosatellite II system provided a space environment of near-zero gravity plus controlled radiation from an on-board strontium-85 source. Insofar as possible it duplicated the normal conditions of a ground laboratory set up on earth as a comparison control. Further, it provided the experiment specimens with all necessary life support requirements, all in a fully-automated module, complete with real-time telemetry on each station pass (about once per orbit) and selective and programmed recording equipment.



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SLIDE 5 BIOSATELLITE IN FINAL ASSEMBLY

The Biosatellite system developed by General Electric's Re-entry and Environmental Systems Division, Philadelphia, Pennsylvania, to perform these tasks is a fully automated space laboratory containing a capsule that can be recovered at the conclusion of its orbital mission so that flight specimens can be compared directly with the ground-based control specimens. This automated system is one of the most complex vehicles ever developed to date. The need for controlled laboratory conditions in a precisely maintained orbit has placed such operational requirements as:

1. Rotational acceleration not to exceed one-ten thousandth of a "g", and to maintain one-hundred thousandth of a "g" 95 percent of the time.

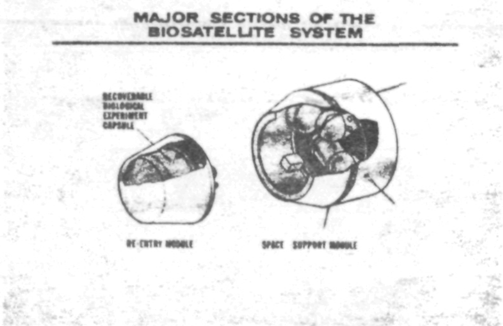
2. A two-gas atmosphere consisting of 20 percent oxygen and 80 percent nitrogen at sea-level pressure.

3. Precisely controlled space-lab temperature, humidity, carbon dioxide and noxious gas concentration.

4. Temperature control of 75° ± 5°.

5. Relative humidity control of 35 percent to 70 percent.

The fundamental reason for such stringent operational requirements is to eliminate the experiment variables, maintaining the environment while in orbit as nearly like the ground laboratory control environment as is possible, except for the added conditions of radiation and weightlessness. Needless to say, such requirements have had major effects on the system design.



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SLIDE 6 MAJOR SECTIONS OF THE BIOSATELLITE SYSTEM

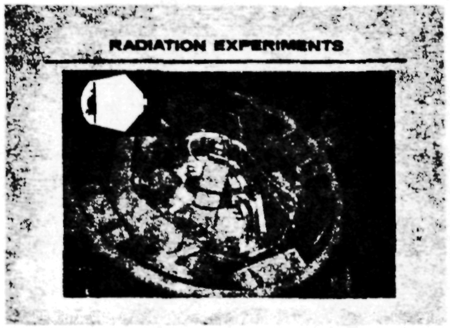
The Biosatellite consists of two major sections as shown here — the re-entry module which returns the specimens to earth, and the space support module which remains in orbit after the mission.

The re-entry module houses the recoverable biological experiment capsule. It is about 102 centimeters in diameter and about 84 centimeters long. The space suppost module is about 145 centimeters in diameter and about 122 centimeters long. Total orbital weight of the system lies between 420 kg and 630 kg depending on the particular mission.

SLIDE 7 BIOSATELLITE EXPERIMENTS

In looking at the total list of ~~dixteen~~ sixteen experiments for the program, a categorization by nominal time in orbit and experiment objectives can be made: THREE DAY for radiation and general biology experiments and THIRTY DAY for experiments on the primate.

As I mentioned earlier, the mission objectives and the experiment duration have had a major influence on the spacecraft design. Thus it might be worthwhile to examine briefly the nature of each of the Biosatellite experiments.



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SLIDE 8 3-DAY MISSION – RADIATION EXPERIMENTS

In the 3-day radiation mission the Biosatellite team was investigating the possibility that radiation effects may be modified by other space flight factors such as weightlessness. The experimenters adapted reliable ground laboratory experiments to the Biosatellite program, using a strontium-85 source. This group of experiments was located in the forward compartment of the recoverable capsule in the re-entry module, as shown in red in the upper left-hand corner of the slide. The radioactive source, enclosed in a tungsten-nickel-copper sphere could be rotated to provide a controlled 200 to 5000 RADS depending on the distance the experiments are placed relative to the radiation source.

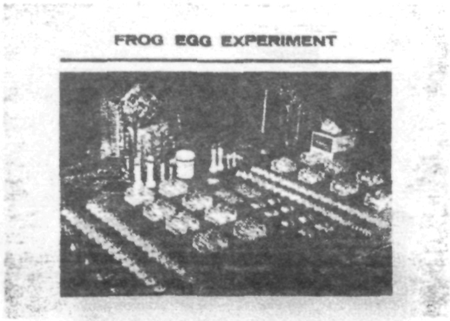
An example of the experiments in this group was the comprehensive investigation of lysogenic bacteria which harbor a virus in an inactive state, attached to the chromatin material of the cell. Under radiation, the virus breaks loose, replicates, and attacks other cells. This particular experiment, employing controlled radiation, identified the independent effects of weightlessness and is the small assembly on the far right of the slide, under the fixture mounting plate.

In all, seven experiments were conducted, involving plants, molds, beetles, fruit flies and wasps, as well as the bacteria I mentioned. Duplicate control experiments were protected from irradiation in a shielded compartment and separated the effects of weightlessness from the combined effects of radiation and weightlessness. The entire 3-day flight radiation sub-assembly is shown here and includes the radiation source holder, the protective shield for the shielded compartment, and some of the experiment packages.

9

SLIDE 9 RADIATION SHIELDED EXPERIMENTS

In a further and equally important study of the effects of weightlessness alone, the general biology group, including plants, frog eggs, and amoeba were carried in the radiation shielded compartment, as shown in red in the upper left corner of this slide. The brown module on the right is the frog egg experiment which typified these shielded general biology experiments. The normal development of a frog egg is gravity dependent, with the vegetal half, being heavier, always at the bottom and the animal pole always on top. If the egg is reversed, abnormal development occurs. This experiment investigated the effect of a weightlessness environment on such eggs.



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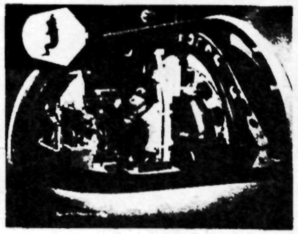
SLIDE 10 FROG EGG EXPERIMENT

The complexity of such a simple sounding experiment is shown on this slide which illustrates the mass of parts that constitute the flight package to automatically carry out the frog egg experiment while in orbit.

PRIMATE EXPERIMENTS



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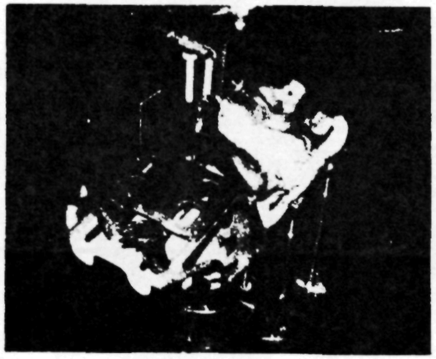

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SLIDE 11 30-DAY MISSION – PRIMATE EXPERIMENT

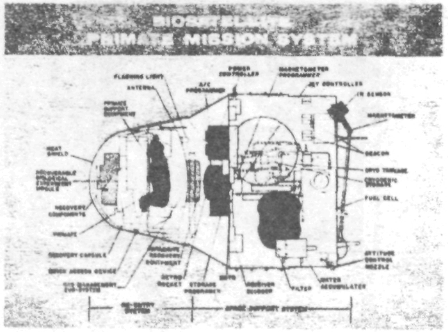
The most demanding of the Biosatellite experiments was the primate mission, which carried a pigtailed monkey, Macaca Nemestrina. This experiment was the first detailed investigation of a high order primate's physiological and behavioral response to space environment. The extensive use of sophisticated medical instrumentation such as deep brain electrodes and heart electrocardiograms permitted the accumulation of data impossible to obtain from astronaut personnel because of their bodily activity during flight.

As I mentioned earlier, Biosatellite III was launched in late June 1969 with primate recovery occurring 9 days later, so experiment results are not fully available as yet. However, some preliminary conclusions have been reached and I shall comment later on these, as well as the performance of the Biosatellite, which met all systems performance specifications. In fact, as planned, the space support module was flown and exercised for the purpose of obtaining engineering data for more than 30 days in orbit.

SLIDE 12 RESTRAINED MONKEY

The primate's central nervous system functions were monitored by electrodes implanted in specific areas of the brain. Sensors in other locations monitored his heart beat, respiration, body temperature, eye movement, brain temperature, and regional blood pressures. Performance, behavior, and decision-making were analyzed through a variety of special purpose devices, such as the psychomotor testing device which the monkey had been trained to operate. A motion picture camera mounted in the capsule photographed the animal at regular intervals during the flight.

Data collected were telemetered to ground stations by real time transmission. In addition, on-board tape recording was provided to record in-orbit information, the effects of re-entry deceleration and the post-impact interval prior to recovery.



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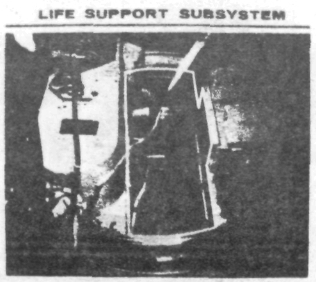

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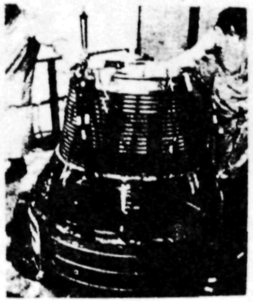
SLIDE 13 PRIMATE MISSION SYSTEM

This slide shows an inboard profile of the Biosatellite III primate mission system. The re-entry module is at the left, attached to the space support module at the right. These two modules house and integrate the eleven subsystems that make up the Biosatellite system. These subsystems are: life support, which includes the gas management assembly, both shown here in light green; thermal control, shown in white; attitude control, shown here in light blue; electrical power and distribution, shown in gray; telemetry, tracking and command, shown in yellow; gas storage, shown in dark green on the slide; separation, shown in dark orange; de-orbit, shown in red, recovery, shown here in light orange; and payload support, which is dark blue.

SLIDE 14 LIFE SUPPORT SUBSYSTEM

The life support subsystems provide, through its gas management assembly, the 2-gas atmoshpere of the capsule. The gas management assembly is located in the re-entry module and controls the environment within the recoverable capsule to provide a habitable atmosphere for the primate at ambient pressure. It also controls the relative humidity and circulation of the capsule atmosphere. Filters containing lithium hydroxide, Activated charcoal, ~~filters~~ ambergist and hopcalite remove toxic and noxious gases ~~as well as any~~ and loose particles are removed by a debris trap ~~and debris~~. The gas management assembly measures, for transmission to ground stations, the cabin relative humidity and temperature, total pressure, and oxygen and carbon dioxide partial pressures. The gas management assembly includes a container of pure oxygen that sustains the primate during re-entry, between separation and retrieval of the recoverable capsule.



THERMAL
CONTROL
SUBSYSTEM

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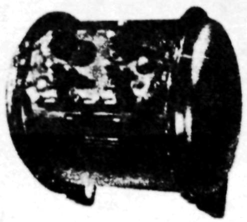
ELECTRICAL POWER AND
DISTRIBUTION SUBSYSTEM
(FUEL CELL)



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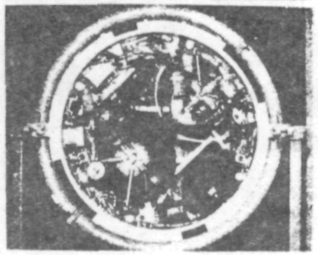
SLIDE 15 THERMAL CONTROL SUBSYSTEM

This slide shows both the Biosatellite thermal control coating that provides passive heating for the Biosatellite system and the radiator that dissipates excess heat. Active cooling is provided by two coolant loops. One loop cools the gas management assembly, exchanging excess heat into the second loop, or alternatively, activating a water boiler. The second loop is used to cool the fuel cell and some of the experimental hardware, and, in addition, supplies some of its heat to the stored hydrogen and oxygen in their cryogenic tanks. Small heaters provide in-orbit heating, as needed, on command from the ground.

SLIDE 16 ELECTRICAL POWER AND DISTRIBUTION SUBSYSTEM (FUEL CELL)

This slide shows the ion exchange membrane fuel cell. Fueled from on-board hydrogen and oxygen supplies, the fuel cell carries all of the electrical load except short-duration, high-peak loads such as squib firing. Short-time loads are carried by a storage battery in the spare support module. In addition to serving as a power source, the fuel cell generates by-product water which, after filtering and treatment, is rendered potable and is used by the primate for drinking. A smaller amount of the generated water is used in the thermal control water boiler. Other batteries in the re-entry module power the equipment during re-entry and recovery.

GAS STORAGE SUBSYSTEM



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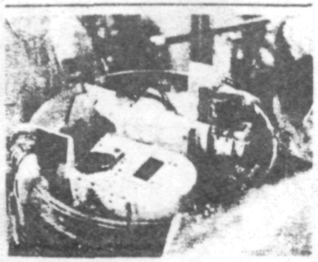
PAYLOAD SUPPORT SUBSYSTEM



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SLIDE 17 GAS STORAGE SUBSYSTEM

This slide shows the gas storage subsystem. Hydrogen and oxygen are stored as supercritical cryogenic fluids in the adapter. They are delivered as gases to the fuel cell or the gas management assembly, as required. The oxygen tank uses an active electrical heater during pre-launch operations and is heated by the thermal coolant loop during orbit, as I mentioned earlier. The hydrogen tank uses an active heater before launch and while in orbit. Nitrogen is stored under high pressure and is delivered through two regulators as needed. One regulator supplies nitrogen to the attitude control system jets. The other regulator provides nitrogen to the recoverable capsule, to the experiment hardware, to the fuel cell, and to the water and coolant accumulators.

SLIDE 18 PAYLOAD SUPPORT SUBSYSTEM

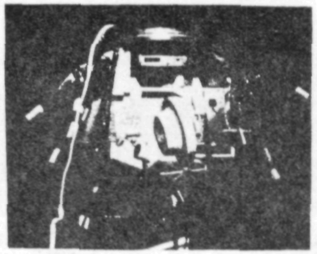
The next few slides will show some of the components that are used to support the primate for duration of the flight.

Food is dispensed as pellets upon actuation of a lever after the primate successfully completes a visual task on the psychomotor device, which you will see on the next slide. The primate has been trained for this, but should it fail to or choose not to perform the task, a ground command override can be sent to arm the pellet feeder.

Included in the payload support subsystem are provisions for a day/night cycle by controlling cabin incandescent lights to cycle bright-dim-bright every 12 hours. Night illumination is deepened.

A 16 mm camera provides film coverage throughout the mission. The camera is forcused on the primate's head and chest and on a calendar clock. It is controlled to expose one frame every 20 minutes throughout the mission. Motion pictures can also be taken at a speed of four frames per second. Primary control of the camera is from the psychomotor tester, but it can also be commanded from the ground.

PSYCHOMOTOR TESTER



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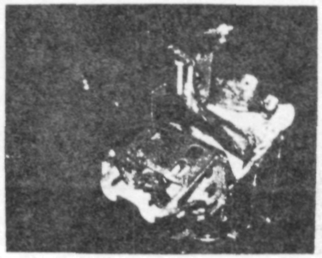
WATER DISPENSER



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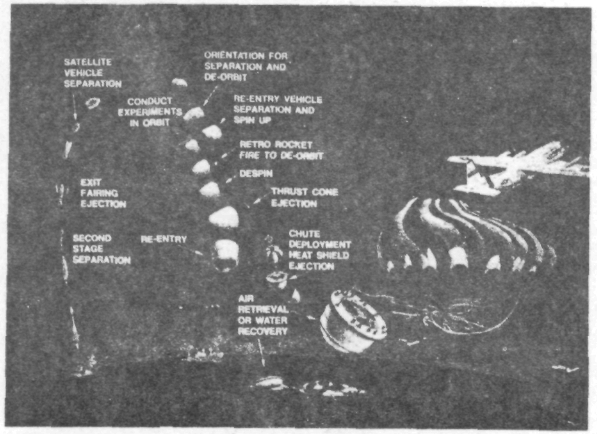
SLIDE 19 PSYCHOMOTOR TESTER

The psychomotor device shown here is used throughout the flight to measure the primate's reaction to stimuli during weightlessness. As I mentioned earlier, he has been trained to perform two tasks. One task involves the matching of symbols which appear alternately in the center and outer windows. The second requires him to press a button which is exposed at intervals through a hole in a rotating ring.

SLIDE 20 WATER DISPENSER

Here we see the physical layout of both the pellet feeder and the water dispenser. Treated by-product water from the fuel cell is always available upon demand, subject to a maximum limit per time period. This limit can always be overridden by ground command and additional water provided. The amount of water used by the primate is metered.



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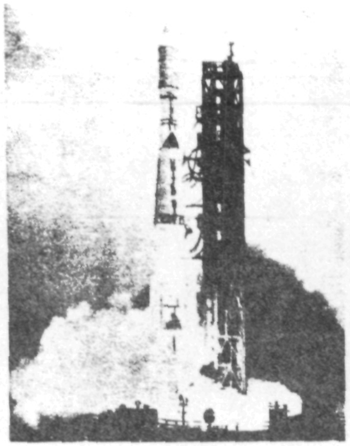
SLIDE 21 BIOSATELLITE MISSION PROFILE

A typical Biosatellite mission profile is shown here. With the separation from the booster (on the left side of the slide), the Biosatellite system is injected into a circular orbit at altitudes as high as 231 miles for the primate mission in order to preclude premature orbit decay.

Looking now at the top of the trajectory, after completion of the scheduled 3 or 30 day orbital period, the attitude control subsystem re-orients the Biosatellite to de-orbit attitude, and the de-orbit sequence begins. The re-entry module separates from the space support module and is spun up for stabilization. (By now, you're at the right of the trajectory). The retro-rocket fires, the re-entry module is de-spun, the thrust cone separates and the re-entry phase begins.

After re-entry, the parachute thermal cover and the heat shield are ejected from the re-entry module and the recoverable capsule's parachute deploys. A radio beacon operates as a location aid to recovery forces during the descent of the parachute. The recoverable capsule containing the payload is then recovered in midair by special aircraft. The recovery operations are such as to permit recovery and return to the laboratory at Hickam Air Force Base, Hawaii for post-flight examination within six hours. If the air-snatch method is unsuccessful, the capsule is floatable, and its beacon, dye-marker system, and other location aids enable recovery from the sea by back-up surface forces.



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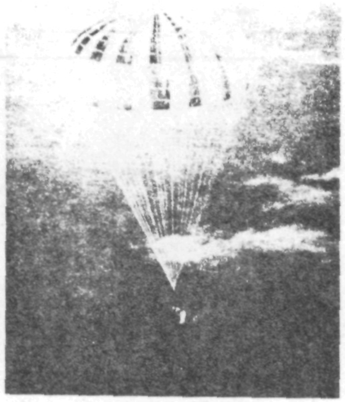

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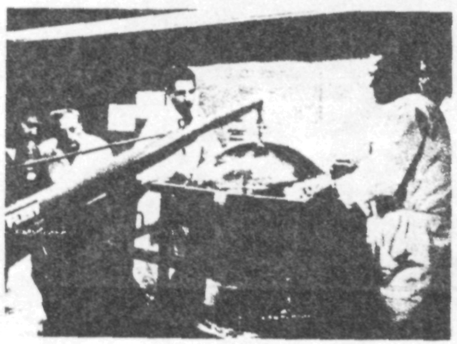

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SLIDE 22 BIOSATELLITE II LAUNCH

This mission sequence was executed very successfully by Biosatellite II, launched September 7, 1967 and recovered on September 9.

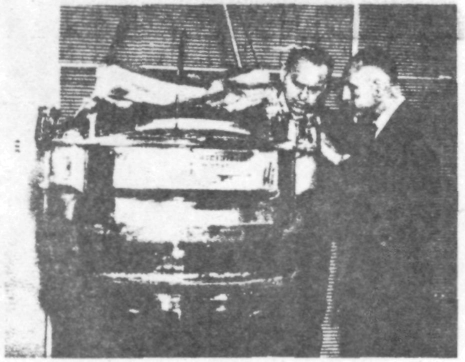
SLIDE 23 BIOSATELLITE II ON CHUTE

The flight culminated in this dramatic view of the recovered capsule suspended from its parachute, taken from the recovery aircraft in the instant before air-snatch. The recovery point was over the Pacific Ocean about 900 nautical miles Southwest of Hickam Field, Honolulu, Hawaii. The actual point of descent was only 15 miles from the location previously predicted, based on orbital data and time of de-orbit initiation. It was readily visible to the C-130 recovery aircraft and was successfully air-snatched on the first pass.

SLIDE 24 POST FLIGHT DISASSEMBLY AT HAWAII

The recoverable capsule with the experiments reached Hickam Air Force Base in Honolulu, Hawaii, at 6:40 PM EDT, just three hours and thirty-one minutes after the capsule was hauled aboard the retrieval aircraft. Within thirty minutes, scientists had their first look at the experiments; within two hours and a quarter, all the experiments had been removed and were under study.

SLIDE 25 RECOVERABLE CAPSULE IN PHILADELPHIA



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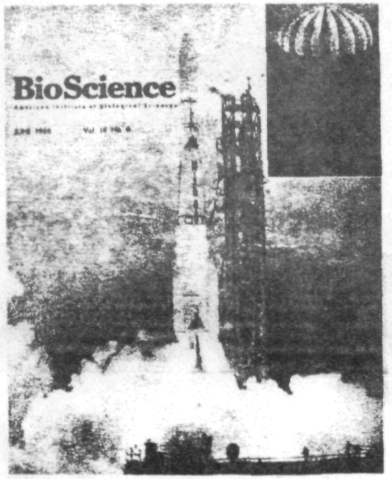
Here you see the capsule back in the General Electric facility in Philadelphia just a few days later. Note that the capsule appears in nearly perfect condition. In fact, our engineers felt that with refurbishment to some external electrical wiring, replacement of the Mylar cover, and a few other minor repairs, the capsule and the sub-systems within could be flown again as has been done on some of our other programs.

Let me take a few minutes now to mention the results of the experiments flown on Biosatellite II.

SLIDE 26 COVER OF BIOSCIENCE MAGAZINE



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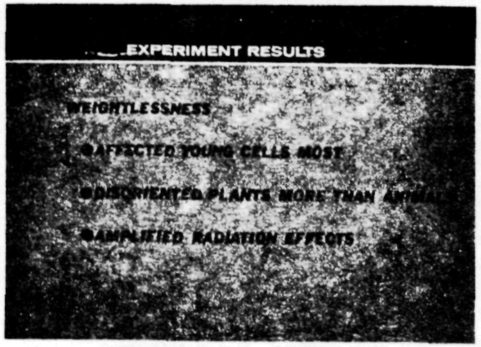
I should point out that I am an engineer, not a practicing biologist, and so my comments on the experiment results will be brief.

For those of you who might wish additional details, the June 1968 issue of "Bioscience," the official publication of the American Institute of Biological Sciences, contains the proceedings of the two-day Symposium on Biosatellite II Experiments Results. This Symposium was held in Washington, D.C. in February 1968 and was sponsored by the National Academy of Science-Space Science Board and NASA.



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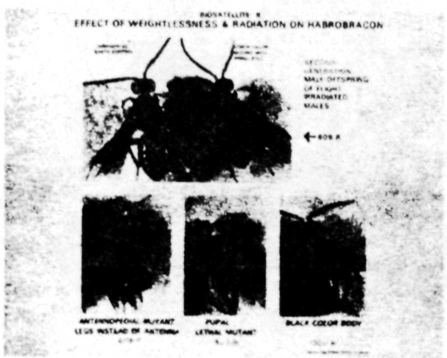

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NOT REPRODUCIBLE

SLIDE 27 EXPERIMENT RESULTS

To summarize the experiment results, then:

The greatest effects of weightlessness were observed in young and actively growing cells and tissues. Rapidly dividing cells with high metabolic activity showed more effects than mature cells, which divide more slowly

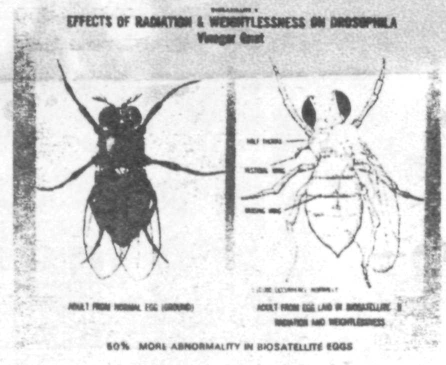
Generally, plants had trouble maintaining proper orientation in weightlessness and some plant structures, mechanisms and biochemical activity seemed to be affected. ~~By contrast, animal cells seem less affected by weightlessness~~.

When plant and animal structures experience radiation in the absence of gravity, both seem to suffer greater damage then the same organisms irradiated on Earth. Again, damage seems to occur principally in young, rapidly dividing cells or in active reproductive cells, and not in mature structural cells. There is evidence that growth and metabolism of rapidly dividing cells is slowed by absence of gravity, giving time for repair of the cells damaged by radiation in the weightless state.

I would like to show you some of the more interesting photos which have been released by NASA.

SLIDE 28 EFFECTS OF WEIGHTLESSNESS AND RADIATION OF HABROBRACON

Eggs from the parasitic wasp (habrobracon) seem to recover from radiation damage in space and to show less genetic damage then the controls. The normal male is at upper left, contrasted with various mutants that have been observed as the results of flight irradiation.



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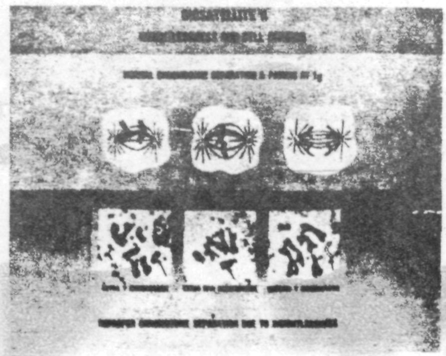

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NOT REPRODUCIBLE

SLIDE 29 EFFECTS OF RADIATION AND WEIGHTLESSNESS ON DROSOPHILA

This slide illustrates one of the abnormalities resulting from eggs of the vinegar gnat (drosophila) laid during the Biosatellite II flight. In adult vinegar gnats, those exposed to radiation in space produced 50 percent more offspring with genetic defects than did the ground controls. Abnormalities of this type (one-half thorax and one wing) normally have an occurrence rate of one in ten thousand.

SLIDE 30 WEIGHTLESSNESS AND CELL DIVISION

In vinegar gnat (drosophila) larvae, irradiated aboard the spacecraft, unusual and disturbed chromosome separations during cell division were observed. Here a comparison is made of normal chromosome separation and pairing at 1 "g" with the improper chromosome separation due to weightlessness. This phenomenom was seen to a lesser extent in larvae carried in the satellite but not irradiated, and not observed at all in the ground controls.

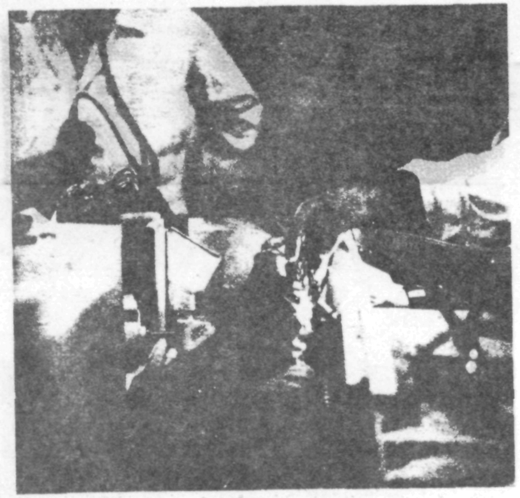
(31)

SLIDE 31 EFFECTS OF WEIGHTLESSNESS AND RADIATION ON TRIBOLIUM

Flour beetles (tribolium) exposed to radiation in space produced twice as many mutations leading to death in offspring as did beetles given identical radiation dosage on Earth. The mutations shown here took the form of split wings and protrusion of membranous wings in the adult.

The findings of Biosatellite II were many and varied. No doubt it will be some time before the full implication of such results are fully understood and the impact on our knowledge of the fundamental biological processes in the space environment are assessed.

I would now like to discuss some of the preliminary findings of the Biosatellite III 30-day primate mission.



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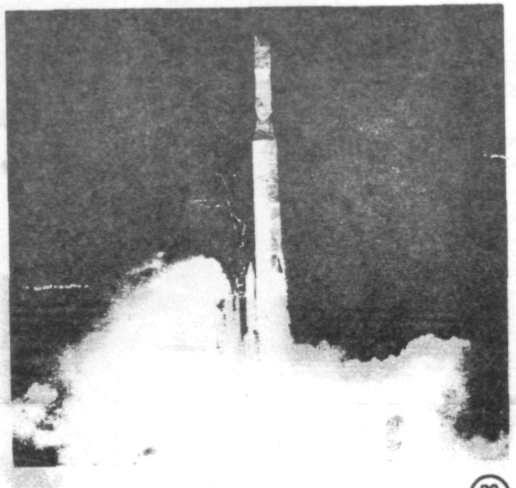

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SLIDE 32 30-DAY MISSION - INSERTION OF THE PRIMATE INTO BIOSATELLITE III

This slide shows the primate being inserted into the spacecraft. Shown in the photograph is the water dispenser nipple, part of the payload support sub-system, and the skull cap containing the brain function electrodes. Five primates were prepared and trained for this mission and the remaining four primates were utilized for ground control purposes.

SLIDE 33 LAUNCH OF THE BIOSATELLITE III

Biosatellite III was launched from Cape Kennedy, Florida, at 11:16 PM, on June 28, 1969. The primate mission was the most comprehensive study ever made of a complex life form in a weightless state, far more so than could have been made with man as the experimental subject. The physiological instrumentation used was painless and did not harm the primate. Approximately 80 percent of the experimental data generated was telemetered to Earth by real-time transmission.

34

SLIDE 34 WATER RECOVERY OF THE BIOSATELLITE III

Because of a marked deterioration of the primate's health as indicated by the real-time telemetry, the mission was terminated on the 9th day with successful deorbit and recovery 25 miles north of the Island of Kauai in the Hawaiian chain. The primate was alive when the spacecraft was opened. He appeared to respond well to treatment and was observed to be recovering until 10 hours after splash-down when he suddenly and unexpectedly died. A preliminary post-mortem examination reported the cause of death as heart failure. It will take several months of further study to complete tissue and organ analyses taken during the examination.

The Biosatellite III system itself functioned almost perfectly within specified performance limits.

35

SLIDE 35 CONTROL PRIMATE IN A SIMULATED BIOSATELLITE SYSTEM

It is now possible to state some early conclusions from the Biosatellite III flight. Nine days of extremely clear and meaningful physiological data on the effect of weightlessness on a man-like animal were obtained, comparable in quality to that obtained from the four control subjects at the Kennedy Space Center, Florida. More than one million bits of information were acquired on the animal's brain, cardiovascular and metabolic functions. These data were acquired in a state of reduced gravity forces much less than that experienced in manned flight because of lesser demands for spacecraft maneuvers.

The Biosatellite experiments have reported several unusual events. For several days prior to the call-down decision the primate's metabolic state was steadily declining. This lower state was indicated by decreasing body temperature, slower heart rate, shallow breathing, and substantial sleeping during the day cycle even though the cabin temperature was at its lower specification limit of 70°F during most of the flight. The primate also showed an apparent drift in body cycle rhythm from the usual 24 to 26 hours even though 12 hour day and 12 hour night cycles were provided by spacecraft lighting and feeding cycles. This rhythm shift became apparent on the second and third day of the flight. This behavior strongly suggests that the primate exhibited a "free-running" cycle that was dictated by its own physiological requirements and not on factors from the outside environment such as day and night. The physiological data obtained has direct application to long-term manned flights and to basic physiology.

BIOSATELLITE III VEHICLE PERFORMANCE

	TECHNICAL OBJECTIVE	ACHIEVED IN FLIGHT
COMMANDS	75 % EFFECTIVE	100 %
DATA	10^{-3} BIT ERROR RATE	$<10^{-6}$
GRAVITY FORCES	$<10^{-5}$g	$<10^{-5}$g
ENVIRONMENTAL CONTROL	75 ± 5° ACROSS PRIMATE	68.6-76°F
	35-70° REL. HUMIDITY	42-58%
	13.2-16.2 PSIA PRESSURE	14.1-14.7 PSIA
	135-165 MM HG PO_2	141-159 MM HG
	0.2-7.6 MM HG PCO_2	0.3-4.3 MM HG

(36)

Slide 36

BIOSATELLITE III VEHICLE PERFORMANCE

	TECHNICAL OBJECTIVE	ACHIEVED IN FLIGHT
COMMANDS	75% EFFECTIVE	100%
DATA	10^{-3} BIT ERROR RATE	$<10^{-6}$
GRAVITY FORCES	$<10^{-5}$g	$<10^{-5}$g
ENVIRONMENTAL CONTROL	67 - 83°F ACROSS STATIC PRIMATE ENVELOPE WITH GRADIENT NOT TO EXCEED 13°F.	69 - 80°F
	35-70° REL. HUMIDITY	42 - 58%
	13.2-16.2 PSIA PRESSURE	14.1-14.7 PSIA
	135-165 MM HG PO_2	141-159 MM HG
	0.2-7.6 MM HG PCO_2	0.3-4.3 MM HG

SLIDE 37 BIOSCIENTIFIC SUPPORT TO MAN'S CONQUEST OF SPACE ENVIRONMENT

Dr. Christian Barnard, the famed heart transplant surgeon of Capetown, South Africa, and General Electric Company scientists are collaborating on a series of space experiments designed to determine what effect gravity has on the mechanisms of cell and organ rejection of transplants. The experiments will use monkey kidney and human lymphocyte cell cultures, white mice, and rats to measure this immunological adequacy for durations from 10 to 18 days with subsequent recovery.

The Biosatellite Program is truly another example of man's ability to cope with the unique aspects of space exploration. This integrated approach to the many problems associated with long duration space travel and man's well-being in the space environment for extended periods can aid in their solution using this and future fully automated bioscience experimentation space systems.