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BIOSATELLITE II Experiment Environment

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D R A F T

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The basic design requirement of the BIOSATELLITE II spacecraft was to provide an automated laboratory suitable for the conduct of biological experiments in a weightless environment. To satisfy this requirement it was necessary to not only protect the experiments from the external environment, but also to provide a controlled atmosphere within the compartment where the experiments were located. The complete vehicle designed to provide this desired space laboratory is described in "BIOSATELLITE II OPERATIONS" by Mr. J. Dyer of Ames Research Center. I would like to focus attention on that part of the spacecraft that contained and supported the scientific experiments.

Reentry Vehicle Description

Figure 1 is a schematic representation of the spacecraft reentry vehicle which not only housed the experiments during orbital flight, but served as the carrier to return them to earth. The reentry vehicle is made up of the experiment capsule, the heat shield and the thrust cone or retro rocket assembly. The capsule is of .035 to .065" thick Al and contained the experiments and all necessary supporting equipment to provide the desired environment for the experiments and to permit recovery of the capsule. The forward payload consisted of those experiments exposed to the onboard radiation source. Experiment packages identical to those in the forward payload were located in the aft payload section to provide controls shielded from the radiation source. Four additional experiments, to investigate the affects of weightlessness alone, completed the aft payload.

The radiation source holder, made of sintered tungsten, was positioned in the center of the backscatter shield and provided complete shielding of the source during launch preparation, launch and recovery, and upon command, exposed the source to subject the experiments in the forward payload to the desired radiation dosage. The holder shielded the aft payload from direct radiation from the source at all times. At the end of the orbital flight period prior to reentry the source holder, by command, retracted the source to the fully-shielded position. The backscatter shield is of .050" thick tungsten bonded between two .008" thick Al sheets and shielded the aft payload from radiation backscatter. Also between the forward and aft payloads is the equipment rack which contained power supplies, FM/FM telemetry, beacon, tape recorder, gas management assembly, and other equipment needed to support the experiments and the recovery operation. The gas-management assembly controlled the atmosphere within the capsule by supplying air from a high-pressure storage bottle as needed to maintain sea-level pressure, and by circulating the air through the capsule and a silica-gel bed, to maintain a uniform atmosphere throughout the capsule and to control humidity.

A heat shield of phenolic nylon and fiberglass varying in thickness from 0.72 inch at the nose to 0.22 inch at the skirt with a thermal-control coating on the outside, foam insulation 1/4 to 1/2 inch thick bonded to the outside of the capsule, and heaters bonded to the interior surface of the capsule wall provided protection against atmospheric heating during ascent and reentry, radiative effects in space, and cooling during the high-altitude parachute descent. Special cooling coils within the capsule, supplied from an external thermal-control unit, provided the temperature control prior to liftoff which included special cooling of the frog egg experiment to a temperature of 42 to 45°F. The tribolium experiment had heaters incorporated in the package to satisfy its special temperature environment of 82 to 90° F. The heat shield and experiment capsule were designed with a special breech-lock type connection at the forward end of the conical section to permit rapid closure after installation of the experiments. This feature allowed the experiments to be installed as late as possible in the launch countdown.

A schematic layout of the forward experiment payload is shown in figure 2. The individual experiments were located at various distances from the radiation source, depending upon the desired dosage, and were arranged to prevent shielding of one experiment by another. The radioactive isotope used for the source was Sr^{85} which is a gamma emitter giving off a single gamma ray of 0.513 Mev energy. The half life of this isotope is 64 days. The strength of the source used in the flight capsule was 360 mr/hr/ 1 meter or about 1.3 Curie. In the shielded position the radiation intensity on the surfact of the source holder did not exceed 50 mr/hr.

Experiment packages were made of polypropylene or Lexan and all brackets and supports were Al. Steel screws were used to attach the packages to the supports and backscatter shield. One or more LiF powder radiation dosimeters and thermisters were located inside or attached to the outside of each experiment package as required to provide information on the radiation and temperature environment of most interest to each experimenter. A film and LiF powder dosimeter, and vibration sensors, were also included in the payload assembly.

The aft payload, shown in figure 3, contained duplicates of the forward payload experiments arranged around the frog egg, amoeba, wheat seedling, and pepper plant experiments. The packages were instrumented the same as were those in the forward payload. Sound pressure level sensors, a vibration sensor, temperature sensors, and two dosimeters were located in the aft payload assembly. One dosimetry package contained two pocket ion chambers, one of 5r capacity and the other of 1r capacity. The ~~other~~ second dosimeter was a nuclear emulsion package in a tungsten well designed to measure the amount of radiation entering the spacecraft from external sources, primarily protons and heavy particles.

Experiment Capsule Atmosphere

The basic environmental requirement was to maintain an earth's sea-level atmosphere in the experiment capsule within limits established by the experimenters. Parameters measured to verify that the desired atmosphere was achieved were total pressure, partial pressure of oxygen, temperature, and relative humidity. Throughout the flight the total pressure and the partial pressure of oxygen remained essentially constant at 14.5 psia and 146 mm Hg respectively. The temperature and relative humidity conditions that were experienced during the entire mission from experiment assembly in the clean room in preparation for launch to capsule opening after recovery are presented in Figure 4. The temperature limits identified on this figure apply in general to all experiments with the exception of the tribolium which, by individual control, was maintained between 80 and 90°F and the frog egg, which required cooling to 42 to 45°F during launch preparation. The temperatures shown are averages for the fore and for the aft payloads. All experiment temperatures were within the required limits with the exception of one Tradescantia and one lysogenic bacteria package which were a maximum of 1.5°F below the lower limit during the first ten orbits. The relative humidity was within the desired limits throughout the entire mission.

Samples of the experiment capsule atmosphere were taken just prior to final capsule closure before launch, and prior to opening the capsule after recovery. The results of the analysis of these samples is shown in figure 5. The acceptable levels established by the experimenters are given as specification values for comparison with the flight capsule data. A number of samples were taken and independently analyzed by ARC and the spacecraft contractor, which accounts for the range in the reported amount of several constituents.

Radiation

An environment of great importance to many experimenters was that provided by the on-board radiation source. The dosimeter measurements indicated that the doses delivered to the individual experiments were in agreement with the exposure time of 42 hours with the exception of the 1,000 r Habrobacon package. The discrepancy noted for this package was caused by an error made in the installation which placed the package at a greater distance from the source than was desired. Photographs of the payload assembly revealed that the mounting bracket had been installed backwards and the resulting distance from the source was confirmed by the measured dosage.

The radiation exposures measured by the Li F dosimeter in the control area were low, varying from 1.22 to 0.60 r. The ion chamber measurements ~~confirmed~~ verified these low values. The nuclear emulsion measurements of the numbers of protons and heavy ions entering the spacecraft indicated an upper limit for mission dose due to protons of 40 millirads and 10.1 traversals of atomic nuclei of Z $\geq$ 20 through each equare centimeter during the flight.

A more complete description of the radiation exposure during BIOSLATTELITE II flight is provided in Preliminary Report on Radiation Exposures During the BIOSATELLITE II Flight. by Dr. John E. Hewitt of Ames Research Center and Dr. H. Schaefer of the U. S. Naval Aerospace Medical Institute which is included in the published report of this meeting. Also, the experimenters will treat this subject in more detail in their reports of the experimental results.

Acceleration, ~~and~~ Vibration and Noise

In addition to the capsule atmosphere and radiation environments the experimenters were interested in the hard environment associated with acceleration, vibration and noise. To measure the acceleration, vibration and sound pressure levels within the experiment capsule it was necessary to devise a system that was compatible with the on-board tape recorder. The tape recorder available for use on the BIOSATELLITE was a seven channel unit developed for biomedical data recording on the Gemini project.

The frequency response ~~was~~ of this recorder is 0.5 to 100 HZ which necessitated the use of a special signal conditioner and analyzer in order to provide an indication of the energy associated with frequencies above 100 HZ. A schematic of this system is shown in Figure 7. The outputs from the single axis vibration sensors were direct recorded on the tape recorder. The outputs from the 3-axis sensor were separated into 4 frequency bands with the 3 to 100 HZ band being direct recorded in the same manner as ~~was~~ were the outputs of the single axis sensors. The remaining bands were recorded on the commutated channel. The noise sensor outputs were recorded on the commutated channel providing an indication of the energy level within each of the 2 frequency bandwidths.

Representative vibration and acceleration profiles for the launch and recovery phases of the mission are presented in Figure 7. Only the most active periods of the flight are shown. The Pogo or "20 Cycle" oscillations are thrust oscillations produced as a result of propellant line disturbances and fuel and LOX pump cavitation coupled with the launch vehicle fundamental compression mode. For BIOSATELLITE II this condition occurred at about 140 seconds after lift off and lasted for about 10 seconds. "MECO" is main engine cut off. The drogue parachute is deployed to stabilize and retard the reentry vehicle prior to deployement of the main parachute. The main parachute is initially in a reefed condition and after 4 seconds the reefing line is severed and the parachute opens fully. The aerial retrieval phase is initiated when the descending parachute is contacted and the capsule is rapidly accelerated to the speed of the aircraft. The vibration environment continues during the time the capsule is trailing behind the aircraft.

~~Longitudinal total~~ The vibration amplitude profiles shown are ~~obtained~~ from the direct record channels of the onboard tape recorder, ~~are shown~~. The levels measured in flight are well within the design and test limits. The acceleration profile for powered flight was reproduced from the launch vehicle telemetry data and the profile for the recovery phase was obtained from the data provided by the FM/FM telemetry system carried by the experiment capsule.

Although the ~~instantaneous~~ vibration response measured by the sensor is of interest when looking at the general picture of the environment, the energy frequency relationship or power spectral density is of more interest to the experimenters. Figure 8 presents the power spectral densities obtained from the liftoff, Pogo and aerial retrieval longifudinal vibration data presented in the previous figure. ~~The power spectral density scale for the "POGO" vibration is greater by a factor of 10 than that for the liftoff and aerial retrieval condition.~~ ~~A~~ The maximum level ~~of about .30 g²/HZ~~ was recorded during Pogo was greater than that for Lift off or Aerial Retrieval by about one order of magnitude. ~~as compared to .02 for lift off.~~ ~~The maximum frequency coverec is 100 HZ because of the tape recorder frequency response limitation.~~ The vibration levels in the 100 to 3,000 HZ frequency range were observed on the commutated channel to be less than 0.5 g during powered flight and reentry. During aerial retrieval vibration levels slightly in excess of lg were recorded in the 100 to 300 HZ frequency range.

In addition to the acceleration and vibration environments shown in Figure 8, the payload was subjected to the acceleration imposed by spin-up and de-spin prior to firing of the retro rocket, actual retro fire, and reentry. Acceleration levels of of less than 2 g's were associated with the spin and retro events. During reentry a maximum decel~~l~~eration of 9 g's was recorded, which is in good agreement with the predicted level of 9.1 g's. The total duration of measurable deceleration during reentry was about 3 minutes. No indication of vibration was observed on the data records ~~covering~~ during the period from spin up to deployment of the drogue parachute.

The spacecraft was required to provide an essentially zero gravity environment during orbital flight. How well this was satisfied may be seen in Figure 9.
Rotational rates of the spacecraft were measured during orbital flight and converted to an equivalent g field acting on the experiments. As shown on Figure 9, the $1X10^{-5}$ g limit specified was exceeded during the first 9 orbits. A constant torque disturbance was assumed in order to estimate the rate at which the acceleration increased between ground station contacts. Based on this assumption it was estimated thatthe acceleration level was above $1X10^{-5}$ g for about 11% of the total orbital flight time instead of the desired 5%. The excessive rates were quickly reduced to within control limits when the rate control mode was activated during station pass. The rate buildup that occurred between station passes when the control system was turned off is believed baused by an unexpectedly long period of outgassing of the plastic insulation foam and potting material used in the spacecraft.

No evidence of noise above the 100 db lower limit of the capsule sensors was recorded except in the 17 minute period of aerial retrieval. During this period sound pressure levels of up to 120 db were recorded in the 20 to 10,000 HZ frequency range. During powered flight sound pressure levels were measured in the region between the spacecraft and the fairing, using the launch less than 2 g's were associated with the spin and retro events. During reentry a maximum deceleration of 9 g's was recorded, which is in good agreement with the predicted level of 9.1 g's. The total duration of measurable deceleration during reentry was about 3 minutes. No indication of vibration was observed on the data records during ~~covering~~ the period from spin up to deployment of the drogue parachute.

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The maximum levels occurred during the lift off and transonic flight ~~regimes~~ regimes. The measured sound pressure level reached a peak overall root mean square value of 138 db during lift off. (Reference level is 0.0002dyne/cm^2). At about 21 seconds after lift off, during transonic flight, the level again was observed to increase to about 135 db. One third octave band analyies of the recorded levels indicated a similarity between the spectra for lift off and transonic flight, peaking at about 640 Hz. The fact that these high levels were not observed on the onboard tape recorder is believed due to the attenuation characteristics of the spacecraft, estimated to be from 20 to 35 db. Although information is not available on the external noise level during aerial retrieval, when the capsule was trailing behind the aircraft, it should be noted that the heat shield was jettisoned and the parachute deployed prior to this event, resulting in a decrease in the attenuation characteristics of the structure surrounding the experiment payload.

Shock

Shock excitation of the spacecraft structure occurred during various events of the powered and recovery phases of the flight. The shock environment wasproduced by firing of pyrotechnic devices to accomplish ~~a~~ separation events and by rocket motor ignition and cutoff. The on-board vibration sensors responded to eleven events. The maximum acceleration recorded was 15 g's, although for one disconnect event there is evidence that the instrumentation was saturated. The spacecraft instrumentation was not capable of providing a complete spectrum of the shock environment because of the 100 HZ frequency response limit of the tape recorder. The results of tests conducted during the spacecraft development program with instrumentation capable of responding to frequencies as high as 7 KHz indicated that the acceleration level in the capsule may be as high as twice the flight recorded values. The development tests also revealed that essentially all the vibratory energy was contained in frequency components below 2 KHz. Although the instantaneous acceleration level associated with the shock environment can be quite high, the duration is extremely short resulting in an environment that is considered to be much less severe than the vibration environment. For example, the analysis of launch vehicle data obtained for the spacecraft launch vehicle separation event during BIOSATELLITE I and II resulted in a determination that the equivalent shock spectrum can be reproduced by a ~~XX~~ .25 to .8 millisecond saw-tooth pulse.

Ground Control Tests

During the flight three ground control tests were conducted in the experiment preparation laboratory at ~~KSC~~ Kennedy Space Center using flight type experiment hardware. Two of these controls, designated I and II, were run simultaneously with the flight and the temperature and relative humidity were maintained essentially constant within the specification limits. In the third control test, designated III, the flight temperature and relative humidity profiles were duplicated as closely as possible. In order to do this, a four hour delay in the time phasing of the flight conditions was required to permit acquisition of flight data. Duplication of the temperature and humidity during recovery was not possible because this information was recorded on the onboard recorder in the flight experiment capsule. Therefore, the profile for this period of the mission was estimated.

A flight type reentry vehicle, excluding the thrust cone, was used for control I. The experiment capsule contained all of the normal spacecraft equipment, with the exception that the capsule atmosphere was supplied from an external air conditioning unit. A live radiation source of the same strength as that used in flight was included in this control. Control tests II and III were conducted in chambers in which the temperature and humidity could be controlled. A radiation source was not used in these tests.

The temperature and relative humidity environments achieved in control III are shown in Figure 10. The flight profile data from Figure 5 ~~xx~~ have been included for comparison with the control values.

The total measured radiation dosage received by the forward payload experiment packages in control I agreed very closely with those experienced in flight. The maximum difference was 5% high for one ground control package. The doses received by most of the packages duplicated the flight condition within 2% or less.

Conclusion

The BIOSATELLITE spacecraft demonstrated the capability to provide a space laboratory suitable for the conduct of biological experiments in the space environment experienced by a near earth orbiting satellite. With a very few exceptions all environmental conditions imposed by the experiments were satisfied and all biological specimens were returned to the experimenters in excellent condition.

Figure Titles - BIOSATELLITE II Experiment Environment