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DECONTAMINATION OF THE AIMP-D SPACECRAFT

F. N. LeDOUX

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TABLE OF CONTENTS

CONTENTS (Continued)

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (Continued)

LIST OF TABLES

LIST OF TABLES (Continued)

DECONTAMINATION OF THE AIMP-D SPACECRAFT

by

F. N. LeDoux

FOREWORD

The purpose of this document is to compile the data on major experiments concerning handling, decontamination, cleaning, coating, and encapsulation of the AIMP-D electronic circuit boards and MOSFET circuitry, special tests on electronic compatability with decontamination agents, decontamination techniques for a lunar orbiting spacecraft (AIMP-D), methods of recovering viable microorganisms from component surfaces, means for enumerating the estimate of viable burden and procedures for clean-room personnel.

DECONTAMINATION OF THE AIMP-D SPACECRAFT

F. N. Le Doux

SUMMARY

Because of the harsh environment of the moon, any contamination of the lunar surface by microorganisms from a spacecraft will remain localized and will not propagate significantly. For this reason, it was determined by the Office of Planetary Quarantine, NASA Headquarters, that sterilization of a spacecraft was not mandatory for lunar missions. However, spacecraft are required to be decontaminated biologically to a low level of viable organisms at the time of launch.

A procedure was developed to achieve effective microbial decontamination using a decontaminating agent that was compatible with the electronic components, conformal coating, and encapsulation material. Previous tests performed on coupons from control strips indicated that complete immersion and agitation of a module in 90% isopropyl alcohol for a minimum of 15 minutes was a practical method for killing and reducing most vegetative cells, and removing entrapped moisture capable of carrying nutrients.

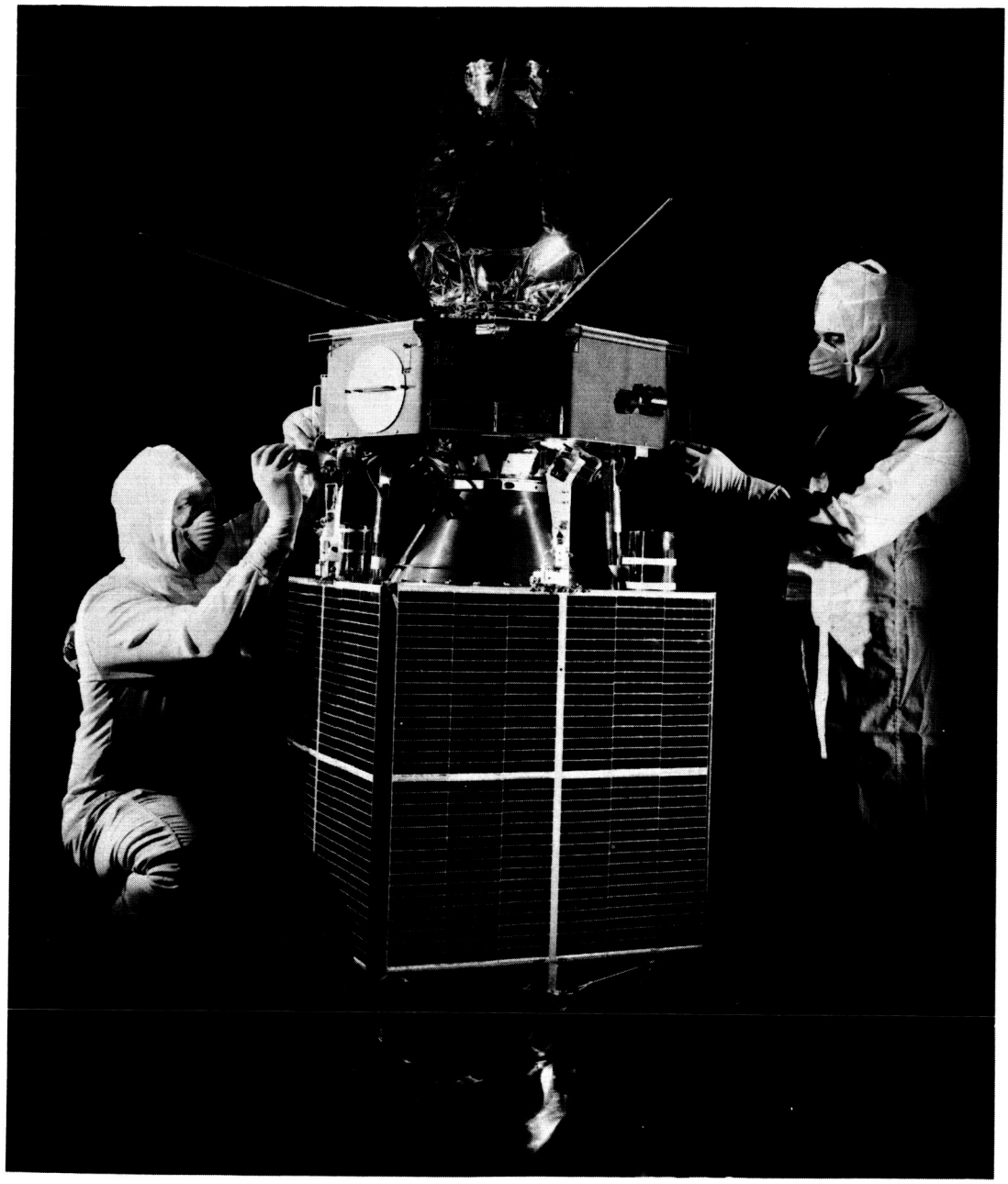
The greatest source of contamination was probably from the technicians, and the debris generated during mechanical integration and assembly. To minimize this a clean room complex was built that allowed for decontamination of spacecraft components, taking bio-samples for assaying, and final assembly.

The total viable count was determined by adding the counts for various areas at the time of occlusion, the counts for all interior and exterior surfaces, and an estimate of the internal burden of components.

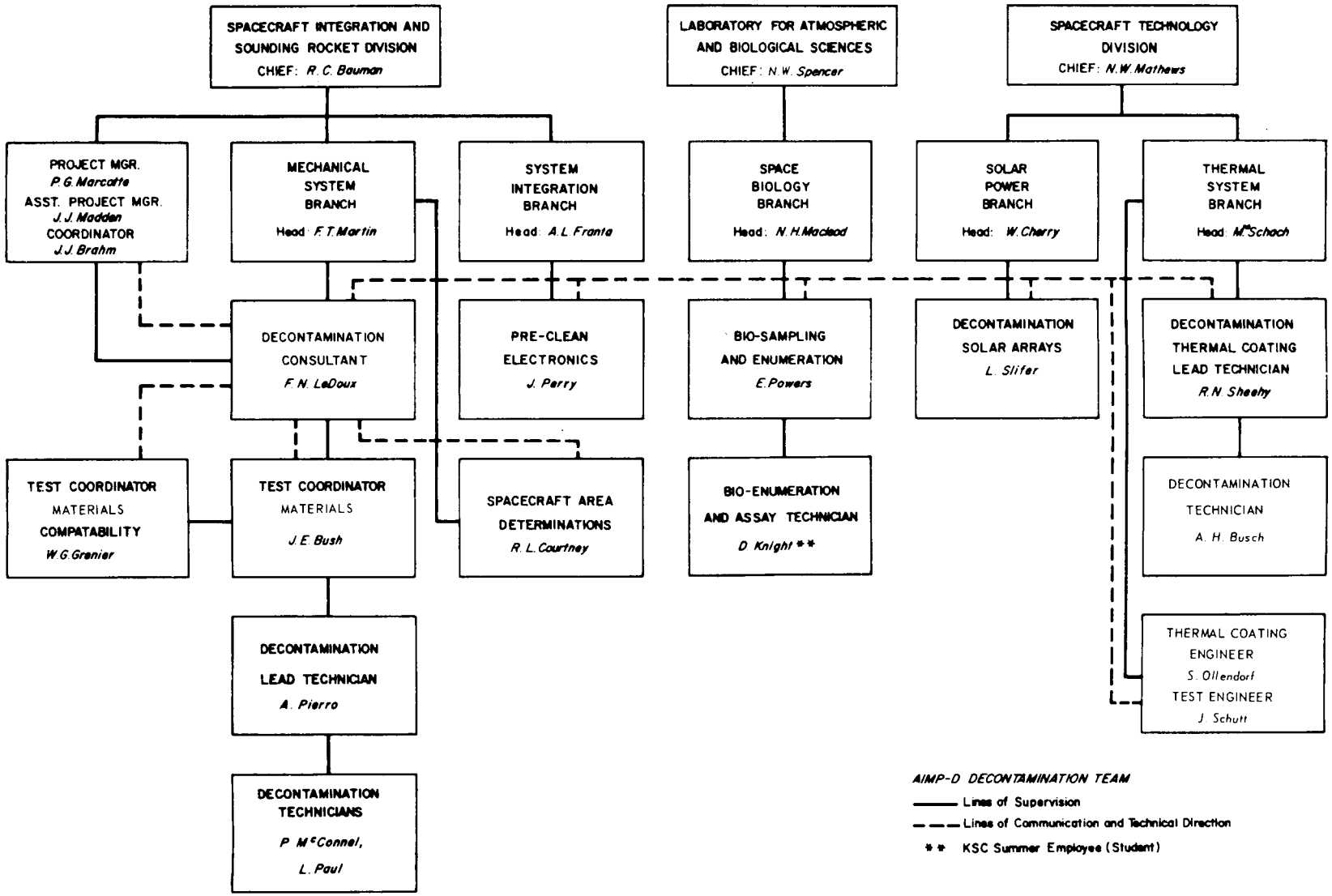
DEFINITIONS

Alcohol	Isopropyl (C_3H_7OH)
Anti-static	Treatment applied to surfaces of insulating materials to obtain conductive qualities.
Asepsis	The prevention of access of microorganisms to materials, components, and spacecraft.
Bacteriostatic	Hindering bacterial reproduction so that microorganisms die after hours, days, or years without a significant increase in number.
Clean	Area or equipment that has been treated to reduce the microbial load.
Clean Test	Treatment for synthetic garments.
Control Strip	A sample or samples of materials affixed to components so that they will be subjected to the same handling or contamination environments as the components themselves. In some cases a spore strip will be used in addition to control strips.
Decontamination	The killing and removal of the greatest number of microorganisms, flora or fauna, which are capable of independent existence.
Disinfectants	Alcohols, formaldehyde, phenol, and its derivatives which will destroy bacteria by: rapid oxidation, coagulation of bacterial protoplasm, diffusion through the cell membrane and chemical combination with bacterial protoplasm, and dehydration by a difference in toxicity between the cell protoplasm and the disinfectant such as in the case of alcohol.
Electrostatic Volt Meter	An instrument capable of detecting and measuring electrostatic charges generated on surfaces of materials.
Germicide	An agent that will kill microorganisms.

MOSFETS	Metal oxide silicon field effect transistors. Also, refers to insulated gate field effect transistors.
Nonsterile	Components or materials presumed to be contaminated with microorganisms.
Plate Count	Measured samples of a culture that is mixed with media (nutrient agar) in a sterile petri dish which have been incubated to required temperatures and then counted. This number multiplied by the dilution factor will give the bacterial count.
Silastic Gasket	Dow Corning Silastic number 50 or equivalent.
Spore	Certain rod shaped bacterial cells capable of forming destructive resting cells.
Spore Strip	A cloth strip inoculated with a known number (10^6) of bacteria which will be subjected to same decontaminating treatment of a component and then immersed into a nutrient broth for a yes or no measurement of sterility.
Sterilant	A sterilizing agent such as ethylene oxide, paracetic acid, dry heat, flame, steam, moist heat and other chemicals.
Sterilization	A process or treatment destroying all viable organisms, including spores.
Ultraviolet Radiation	Radiation in the 2537 Å band.



Frontispiece–AIMP-D Spacecraft



AIMP-D Decontamination Team

DECONTAMINATION OF THE AIMP-D SPACECRAFT

F. N. LeDoux

INTRODUCTION

Because of the nature of the AIMP spacecraft mission near the vicinity of the moon, it is mandatory that particulate matter capable of sustaining microbial forms of life be held at a low level. It is required that operations conducted at Kennedy Space Center and the experiment checkouts, at Goddard Space Flight Center (GSFC) on component parts of the spacecraft system be performed in a clean-room environment. During clean-room operations in which spacecraft components are handled or various tests are being conducted, microorganisms from personnel and tools will contaminate the component or components being worked on. In order to keep contamination at a low level, it is necessary that a standard procedure be applied to reduce the biological and particulate population.

In addition to problems associated with contamination, there are problems associated with electrostatic charges which must be resolved. The problems and definition of electrostatic charges have been aptly stated by Mr. Harry W. L. Street, System Review Office, and are repeated here.

In the metal-oxide silicon field effect transistor (MOSFET), the gate electrode is insulated from the silicon wafer by a thin layer of silicon oxide. This insulating film can be damaged by the application of potential differences of less than 100 v. Since the insulation resistance is high and the gate capacitance is small (<10 pf), a small charge will damage the insulation. Such a charge can be transferred easily from a surface or object which has been electrostatically charged by friction due to people moving around in normal activity. It is essential to avoid conditions which give rise to static charges when handling MOSFET's and equipment containing them.

When the surfaces of two dissimilar materials are merged, a transfer of charges (electrons) occurs at points of intimate contact. If the surfaces are rubbed together, this increases the number of points (small areas) of intimate contact, and increases the total charge transfer. When the surfaces are separated, a potential difference appears and increases as the surfaces separate. If one (or both) of the materials is a good insulator, the charges remain frozen on that surface for a considerable length of time. If another object is at a different

potential (such as one of the leads of a transistor) and approaches that surface, a spark may occur, transferring some charge to the second object. If a conducting object is insulated from ground and other neighboring objects, and rubbed on an insulating material, the charge transferred to the metal object will be distributed over the entire object after separation, since the charge on a conductor is free to move about. If the conducting object is brought to an object at ground potential all of the stored charge will discharge in the resultant spark, releasing a large amount of energy.

An example of this is an individual sliding his shoes (with leather soles) as he walks across a carpeted floor and proceeds to touch a door knob. A spark will occur between the door knob and the individual. When two conductors are rubbed together, charges cannot remain frozen in position on either surface, and it is impossible to separate the surfaces rapidly to prevent neutralization of all charges by a current flowing through the last point of contact.

SATELLITE DECONTAMINATION ROOM

This facility was designed to ensure that potential lunar landing spacecraft will carry the lowest possible level of biological contamination. Located in the Mechanical Systems Branch, GSFC, it is used to decontaminate the spacecraft and its components. The spacecraft will eventually orbit the moon, and due to gravitational pull it will impact on the moon. When this occurs, scientists want to be sure that viable organisms from the earth will be at a low level and will not contaminate the surface of the moon.

Early Tests — Tests conducted by Francis N. LeDoux, Head, Structures and Mechanical Applications Section and AIMP decontamination consultant, have indicated that particulate contamination in the facility is below NASA required levels for class 100 clean room. The preliminary design and specifications for the ultra-clean facility were provided by F. N. LeDoux. Final design, engineering, and manufacturing were provided by Moore & Hanks Co., El Monte, California. The facility consists of four separate rooms with an area of 600 square feet (Figure 1). Room A is a personnel preparation room with a brush vacuum mat at the entrance of the door to clean shoe bottoms. A closet with sterile clothing and a surgical wash basin is included. Room B, a small anteroom, is an airlock with a built-in air shower. The air shower has a 40-mph wind that lasts for 25 seconds and is designed to remove lint and skin scales from the skin and clothing of personnel. Room C is a work area containing decontaminating and monitoring equipment, a positive-pressure air system and an interlocking system on the doors allowing one door to open at a time. This arrangement prevents the pressurized air system from being overridden.

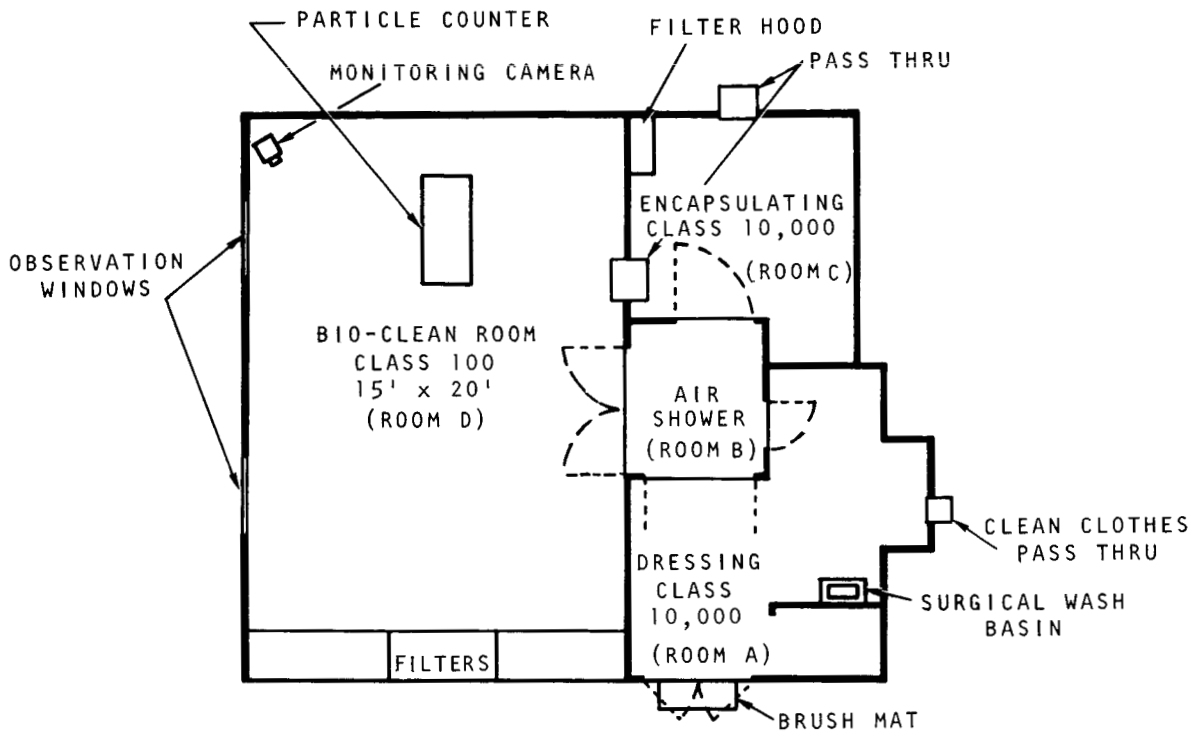


Figure 1–Decontamination Room Floor Plan

Room D is a bio-clean room where satellites are decontaminated. An unusual feature of this room is a monitoring camera which photographs the satellite and personnel every 5 seconds. This feature was included to check on faulty operations that may occur while in the bio-clean room. Horizontal, laminar-flow air emanates from a 14-foot wall via modules with Cambridge high efficiency particulate air (HEPA) filter units. Filtration tests confirmed a rating for this room between 0 and 66 particles of 0.5 micron and larger per cubic foot of air. Walls are of prefabricated panels with a 4 inch insulation of plastic foam. Epoxy-coated steel forms the interior surfaces. A completely lighted ceiling gives a shadowless, 200-foot candle illumination at working levels. There are a minimum of 20 air changes per hour at a temperature range of 67°F to 77°F and a relative humidity level of 40 to 45 percent. A constant temperature of 72°F was maintained. A central built-in wall-type vacuum system is provided in all four rooms, along with observation windows that are double-paned and sealed. Also included are pass-through chambers containing interlock doors to assure maintenance of a positive air-pressure when parts are brought into the room.

PROCEDURES, TEST, AND RESULTS

Decontamination, Cleaning, Coating, and Encapsulation of Electronic Circuit Boards

This section describes a procedure that was used by the Mechanical Systems Branch in the cleaning, decontamination, conformal coating, and encapsulation of electronic circuit boards (ECB's) and electrical connectors for use on the AIMP-D and -E spacecraft. The purpose of the procedure was to obtain decontaminated components that were free of microorganisms for assembly and integration into the spacecraft prototype and flight units.

All ECB's and electrical connectors were first inspected for compliance with specifications by personnel from the Spacecraft Integration Branch. Electronic circuit boards and electrical connectors, cleaned, decontaminated, conformal-coated, and encapsulated by Mechanical Systems Branch personnel were accompanied by an inspection certificate that was signed by a person authorized by the Head, System Integration Branch. Any waiver of the preceding requirements had to be authorized by the AIMP-D and -E project management office.

Inspection — Polaroid photographs were made of all incoming ECB's prior to cleaning, coating, and encapsulation. All photographs were serialized; photograph numbers were logged in the assembly and quality control book and the decontamination and encapsulation record book. Also, photos were filed in the photographic section of the decontamination and encapsulation record book.

Electronic circuit boards and connectors were inspected visually using a 15-power stereo macroscope to detect solder spatter, metallic whiskers, damaged leads, flux, scratches on printed circuits, cold-solder connections, evidence of excessive heat, foreign material, need for stand-offs, damaged sleeving, and bent pins. Any discrepancy found was noted on a red tag and then logged in the appropriate record book as a red tag item. Personnel were required to report discrepancies to the Section Head, and deliver the tagged item to him.

Preparation for Coating — One section of the control strip was removed and placed in a sterile petri dish. A technician marked the number "1" (dirty sample) on the outside top cover with a red grease pencil along with the date, the name of the component, and the serial number. He then placed the petri dishes in the control storage cabinet and the electronic circuit boards and connectors in a container. He carried the container into room A (Figure 1) and placed it on a table. The technician was required to wash his hands and wipe the outside of the plastic container with a cloth saturated with a germicide. He then

inserted the container in a sterile plastic bag and placed it on a table. At this point, he was required to wash his hands again and dress in clean-room clothing. After he was dressed, he cleansed his hands in a germicide, dried them with air and put on sterile gloves. He then carried the bag and container through the air shower (room B) into room C and placed it under the hood. As an alternate method, electronics to be coated or encapsulated were carried through the clean-room pass through window (Figure 1).

Cleaning and Decontamination — All cleaning and decontamination was performed under a fume hood. The ECB soldered connections were brush-washed with xylene and a clean, natural-bristle brush for 10 to 15 seconds. The ECB's then were rinsed in a fresh 85- to 95-percent isopropanol bath and brush-washed with a clean, natural-bristle brush for approximately 3 minutes. The components were then hung on a hanger under the hood and drained for 5 minutes.

Next, the ECB's were placed in a preheated oven at +55 (+0, -5)°C for 5 minutes. If white spots appeared on the board around the soldered connections upon removal from the oven, the cleaning procedures were repeated. The ECB's and connectors were then placed in a fresh isopropyl alcohol bath for 15 minutes. The edges of the ECB's were grasped with rubber gloves and agitated with a twisting motion of the wrist three times. Again, the components were hung under the hood on a hanger and drained for 5 minutes. The ECB's and connector were placed in a thermo-vacuum chamber with temperature preset to +55(+0, -5)°C. The pressure was reduced to 1×10^{-1} mm. Hg. and maintained at a constant temperature for a minimum of one hour. The vaccum chamber was then back-filled with dry nitrogen gas. The items were removed from the chamber with sterile gloves and placed in a sterilized container. The container was then placed under the fume hood and remained there until the ECB was to be coated.

Conformal Coating and Preparation — The edges of the ECB's were masked with a teflon pressure-sensitive tape with a 1/16-inch lip around the perimeter of both sides of the ECB. The items were continued to be handled with sterile gloves and placed in position on a turning stand under the fume hood. It was necessary for the turning stand to be sterilized prior to being placed under the hood. The mother board was not conformal-coated on the side where the submodule lead wires pass into the mother board. This allowed removal of the submodule in case of failure.

A mold release and protective covering, where called for by the experimenter or cognizant engineer, was applied. Connectors were not dipped, poured, or spray-coated. It was required that they have a mating connector attached and taped so that no conformal coating entered the connector body or deposited on its exterior.

The ECB's and control strip were thoroughly saturated by immersion in conformal coating (nonrigid epoxy type, such as Biggs #823) (Table 1). Repeated pourings or brushing was acceptable if immersion was not possible. The ECB layouts determined the correct method. If the coating method was immersion or pouring, the ECB's were removed from the turning stand; but if the coating method was spraying, the ECB remained on the turning stand and rotated while spray coating was applied. The coated items on the turning stand received direct rays from infrared heat lamps and were mechanically rotated until the epoxy polymerized. The ECB temperature did not exceed 45°C during polymerization, including exothermic of epoxy. The formulation for the epoxy resin system that was used in conformal-coating the electronic components is given in Table 1.

Table 1
Formulation for Epoxy Resin System

Material	Proportion (% by wt.)	Description
Epoxy resin	64	Biggs No. 823, 100% solids Viscosity: 600 poises at 175°F Epoxide equivalent: 175-195
Polyamide resin	12	Versamid 125 Viscosity: 80-120 poises at 40°C Amine value: 290-320 Specific gravity: 0.97
Allyl glycidal ether	20	
Hardening agent	4	Shell Z Viscosity: 20 poises at 80°C Aromatic amine, liquid type

The material in Table 1, when prepared and used in the manner prescribed in this document will have the following qualities:

1. Bacteriostasis
   a. Bacillus subtilis var niger
   b. Staphylococcus aureus

c. Pseudomonas alcaligenes

d. Corynebacterium spp

2. Electrical Characteristics

a. Dielectric constant and dissipation factor based upon an average of four samples:

Frequency	Dielectric Constant	Dissipation Factor
1×10^3	4.36	0.0070
1.2×10^6	3.90	0.0187

b. Volume resistivity 10^{15} ohm cm

c. Dielectric strength (based upon six samples) at 60 Hz root mean square (RMS): the highest value was 1560 v/mil; the lowest value was 110 v/mil. It was concluded that the lowest value sample had either pinholes or foreign material imbedded in the coating. However, the average of the six samples was 590 volts per mil, and it is therefore considered a very good material for the purpose intended.

3. Outgassing

Figure 2 shows the outgassing rate for one sample of conformal coating that was conducted after 24 hours of cure time. The curve is an approximate one because of variables that could not be pinned down; e.g., pumping speed and pressure. The weight loss is a before-and-after type measurement. It can be assumed that the greater portion of the 1 milligram loss occurred in the first hour or so because of water and other deposits on the surface of the sample prior to, and during, injection into the vacuum chamber.

4. Mechanical

a. Withstands Delta and Scout prototype and flight level vibration tests.

b. Over 160,000 components have been coated to date without any mechanical failure attributed to the conformal coating.

c. Torroids could not be successfully coated without damage to the very fine wires. Do not coat.

Cure and Decontamination – The coated ECB's and connectors were removed from the fume hood and placed in the oven, which was preheated to 55 (+0, -5)°C. They remained at this temperature for a minimum of 4 hours and then were assembled into their frames. Prior to the assembly, one section of the coated control strip was removed and placed in a sterile petri dish. A No. 2

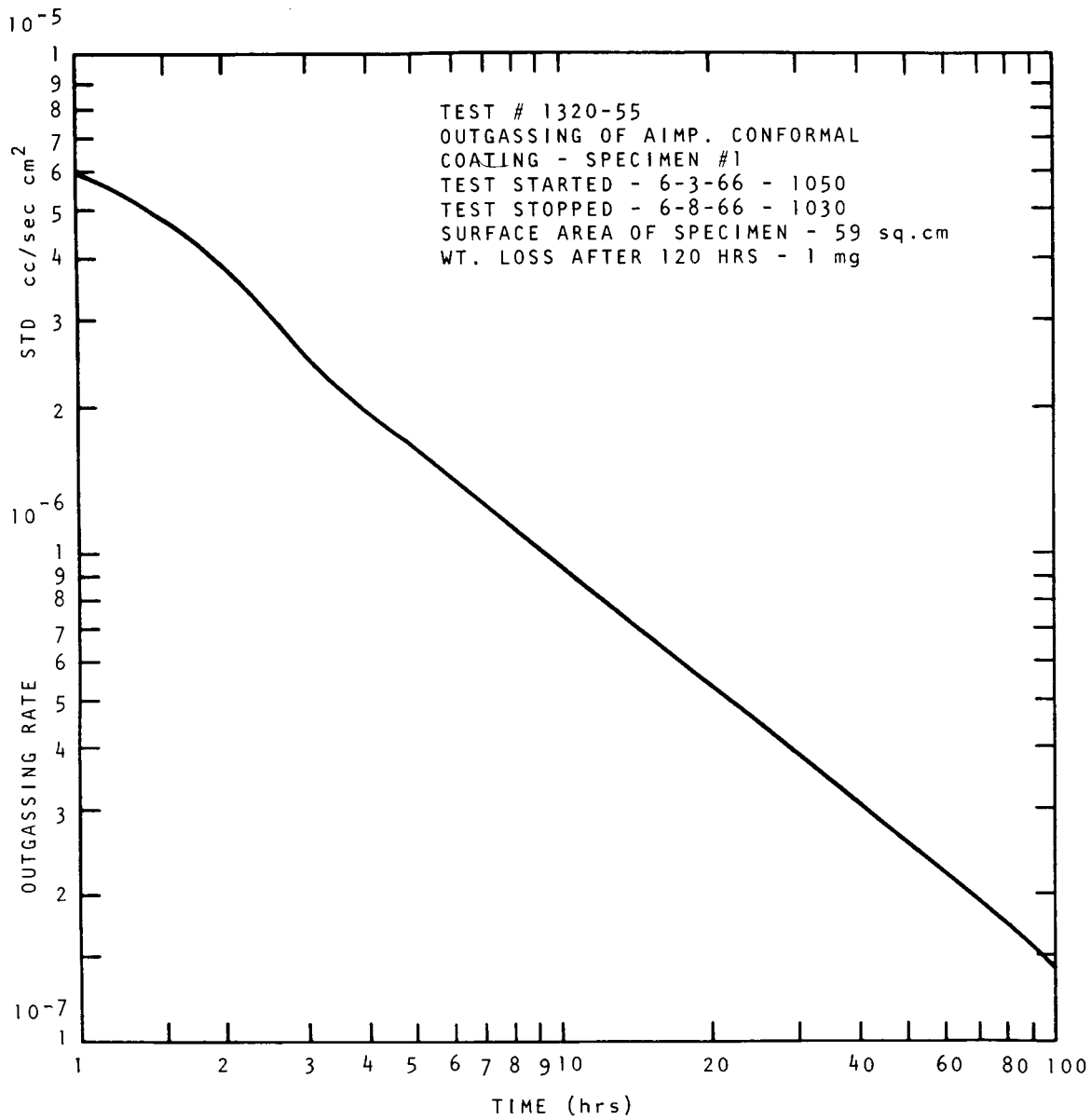


Figure 2–Outgassing Rate on Samples of Conformal-Coated Test Strips

mark (clean sample), date, name of component, and serial number were placed on the outside top cover of the petri dish with a green grease pencil. Petri dish was placed in a control storage cabinet, and coated item immediately placed into its container. The container with coated and decontaminated items were placed in the storage cabinet provided for this purpose.

NOTE: The containers with coated item were removed from the clean room area utilizing the pass-through window.

Encapsulation – The ECB's and electrical connectors encased in an encapsulant were handled as previously described for other ECB's and connectors. The item was placed directly under the fume hood. One section of the control strip was removed and placed in a sterile petri dish with proper markings (mark No. 3, dirty sample, etc.) using a red grease pencil. The petri dish was again placed in the control storage cabinet. For ECB's that were conformal-coated, the procedure previously mentioned was used; the same was true for the items not conformal-coated. ECB's were then decontaminated and the remaining section of the control strip was removed for assaying. The ECB's were then encapsulated with Eccofoam FPH mixed 5 to 8 lbs/cu ft in density. Entries that were pertinent to encapsulation were made on the conformal coatings and encapsulation record form, 670-24 (8/64). The encapsulated ECB's were placed in containers and stored in the instrument storage cabinet.

After the electronic cards were encapsulated with Eccofoam, they were mechanically integrated into the spacecraft, under aseptic conditions.

Handling, Cleaning, Decontamination, and Encapsulation of MOSFET Circuitry

This section describes a procedure that was used by the Mechanical Systems Branch in the cleaning, decontamination and encapsulation of metal-oxide silicon field effect transistor (MOSFET) circuits. The purpose of this procedure was to obtain decontaminated and encapsulated electronic circuits containing MOSFET's that were reliable and undamaged by the effects of electrostatically charged surfaces with which personnel probably came in contact.

Pre-Encapsulation Inspection and Certification – All electronic printed circuits and welded modules were inspected as specified by the Head, Spacecraft Integration Branch and the Project Manager. Any electronic circuit or electrical connector that was cleaned, decontaminated, conformal-coated, and encapsulated by the personnel of the Mechanical Systems Branch was processed and handled as mentioned previously. Any waiver to the preceding requirements was issued by the project management office.

Handling Requirements for Delivery — Prior to delivery to the Structural and Mechanical Application Sections clean room for encapsulation the modules containing MOSFET's were required to be in metal containers that were furnished by the Mechanical Systems Branch, and affixed in a manner to prevent any movement of the module within the container. The teflon sleeves were removed from the leads after being wetted with alcohol and were kept separated by means of a drilled fiberglass board that also was first wetted with alcohol.

Clean Room and Personnel Preparation — Prior to removing modules from the metal containers, all personnel adhered to the following steps:

1. Affix leg stats.
2. Attach a grounding wire from an electrostatic voltmeter to the ground plate (clean room floor).
3. Take a reading of the static charge (if any) on the module at a distance no greater than 12 inches from the module.
4. Take a reading of the static charge on clothes and gloves, and on all glass and plastic surfaces in the encapsulation area of the clean room.

The modules were not to be moved from the containers until all static charges were eliminated from the surfaces with anti-static spray. If clean room clothing showed a static charge, the garments were replaced with garments that were free of static charges or sprayed with "Clean Test."

Pre-Encapsulation – In this procedure, the grounding wire was attached to the metal container containing the MOSFET circuit module. A sheet of aluminum foil was placed on the balance, and the balance was grounded to the ground plate (floor of clean room). The module, fiberglass lead separator, wire leads, and the bottom surface were thoroughly wetted with alcohol. Then the module was removed gently from the container along with the fiberglass separator board and placed on the aluminum foil-covered balance, while being monitored with the electrostatic voltmeter. The module was weighed (weight of foil deducted) and the weight was recorded on an encapsulation record sheet. Then it was removed gently from the balance and placed under the hood on a grounded metal foil.

Mold Assembly — To assemble the mold, it was first necessary to wet the silastic gaskets with alcohol and fit them onto the wire leads at both ends of the mold. Module and gasket fittings were completed only when the entire assembly was wet with alcohol. Static charges that may have built up during many of the operations were monitored and, if any static charges had built up on the surfaces of the module, encapsulation operations were halted and the supervisor was immediately notified. The ends of the molds were assembled over the silastic

gasket, and the sides were assembled to the remaining portion of the mold to determine the fit; if necessary, adjustments were made to the mold. Then the sides were removed from the mold with the ends pre-assembled and the leads protruding. The entire module with the two gasketed and fitted sides were immersed in a fresh propanol bath. The module remained in the bath for a minimum of 10 minutes and was agitated several times before being removed. After removal from the alcohol bath, it was hung on a hanger under the hood and drained for 5 minutes. Then the module was placed on a grounded sheet of aluminum foil in a thermo-vacuum chamber. The temperature was raised to 55(+0, -5)°C, and pressure was reduced to 1×10^{-1} mm Hg. Temperature and pressure were maintained for a minimum time of one hour. All transfer operations were monitored for static-charge buildup.

Preparation of the Mold for Encapsulation — This part of the procedure required that all potting material left from the previous encapsulation be removed from the bleed holes in the mold. Then the mold was brush-cleaned in alcohol and dried under the hood. The inner portion of the mold, mold cover, and base were sprayed with mold release and dried under the hood.

Encapsulation — After the module was in the thermo-vacuum chamber for one hour, it was back-filled with dry nitrogen and removed. It was handled with gloved hands, wetted with alcohol. The exposed portion of the silastic gasket was brushed with alcohol. Then the gasketed module and fitted sides were fitted to the remaining portion of the mold that was previously sprayed with mold release. All mold parts were assembled in place while the operation was monitored for possible static charge buildup. The required amount of Eccofoam FPH, for a density of 6 to 10 pounds per cubic feet for a finished module, was injected into the mold through the hole provided for this purpose. The mold was placed in an oven preheated to 55(+0, -5)°C for a 1-hour cure, removed from the oven, and cooled to room temperature on the grounded aluminum foil placed under the hood. After the mold was cooled, it was immersed in a alcohol bath with its encapsulated module. The module was removed from the mold and the gaskets were removed from the lead wires while the entire assembly was immersed in alcohol. Excess encapsulant was removed and trimmed while still wetted with alcohol. Then the encapsulated module was placed on the grounded sheet of aluminum foil on the balance and weighed. Its weight was logged in the appropriate record book and on the tag accompanying the module. The metal container that held that encapsulated module was then grounded. The module was removed from the balance with a gloved hand wetted with alcohol and placed into its metal container with a restraining strap holding the module in place.

Biological Decontamination of a Spacecraft System

Because of the harsh environment of the moon, any contamination of the lunar surface by microorganisms from a spacecraft will remain localized and will not propagate significantly. For this reason, it was determined by the office of Planetary Quarantine, NASA Headquarters, that sterilization of a spacecraft was not mandatory for lunar missions. However, spacecraft are required to be decontaminated biologically to a low level of viable organisms at the time of launch.

For the purpose of this document, biological decontamination is defined as the killing and reduction of viable microorganisms which are capable of existing independently, and the removal of all other residuals which may serve as nutrients to support microbial life. Components are considered sterilized when they have been exposed to high temperatures in an autoclave (moist heat) or by dry heat sterilization, and the reliability of the system has not been affected by the temperatures. In all other cases, biological decontamination means sterilization of as many surface areas as possible.

Flux Solvent Efficiency — Prior to the inauguration of a program for biological decontamination of spacecraft systems, several tests were conducted on the following factors.

1. Effectiveness of flux solvents
2. Agents for bacteriacidal action
3. Compatibility of spacecraft materials with a bacteriacide
4. Method of recovering viable microorganisms from component surfaces
5. Means for enumerating the estimated viable count at the time of launch
6. Developing a method of aseptic handling, assaying biological samples, and final assembly

A decision was made to use several solvents that could effectively remove residual flux deposits and other foreign materials that were present on the electronic instrumentation modules. Four solvents were evaluated, but two were eliminated early in the testing program, although they were adequate for cleaning purposes, they were responsible for a rapid deterioration of the rubber gloves used by the technicians in applying solvents. It was recognized that Xylene and Moore-50 solvents caused some deterioration of the gloves but at a less rapid rate. A summary giving test results conducted using Xylene and Moore-50 solvent in Table 2. These solvents were used in conjunction with resin fluxes extracted from Ersin multicore solder, Kester core solder (#66), and Kester plastic core solder.

Table 2
Flux Solvent Efficiency Test Results

Flux			Flux Cleaning Time With Solvent (seconds)	Average Effectiveness of Cleaning (%)
Cleaning Solvent	Type	Average Mass mg		
Xylene	Ersin Multicore	113	15	100
	Kester Core #66	119	15	100
	Kester Plastic Core	73	15	100
Moore M-50	Ersin Multicore	98	15	99.8
	Kester Core #66	87	15	99.7
	Kester Plastic Core	87	15	100

The average mass of flux deposits that was used in conducting a solvent efficiency test was 96 mg. The average amount was approximately four times the amount expected to be found on a circuit connection. A 15-second cleaning time was constantly maintained for each of the reported tests.

Bactericide Efficiency — A procedure was developed to achieve effective microbial decontamination using a decontaminating agent that was compatible with the electronic components, conformal coating, and encapsulation material. Samples of each material listed in Appendix A were tested for compatibility with bactericide used. Previous tests performed on coupons from control strips indicated that complete immersion and agitation of a module in 90-percent isopropyl alcohol for a minimum of 15 minutes was a practical method for killing and reducing most vegetative cells, and removing entrapped moisture capable of carrying nutrients. Filtering the used isopropyl alcohol proved that the viable spores were washed free from the surfaces of electronic components. It was noted that free spores in the alcohol were capable of contaminating other items to be decontaminated; therefore a filter system (Figure 3) was set to filter out particles 0.5 micron and larger in diameter. Prior to reusing any of the alcohol for decontaminating purposes, it was filtered through the system for a period of 5 minutes.

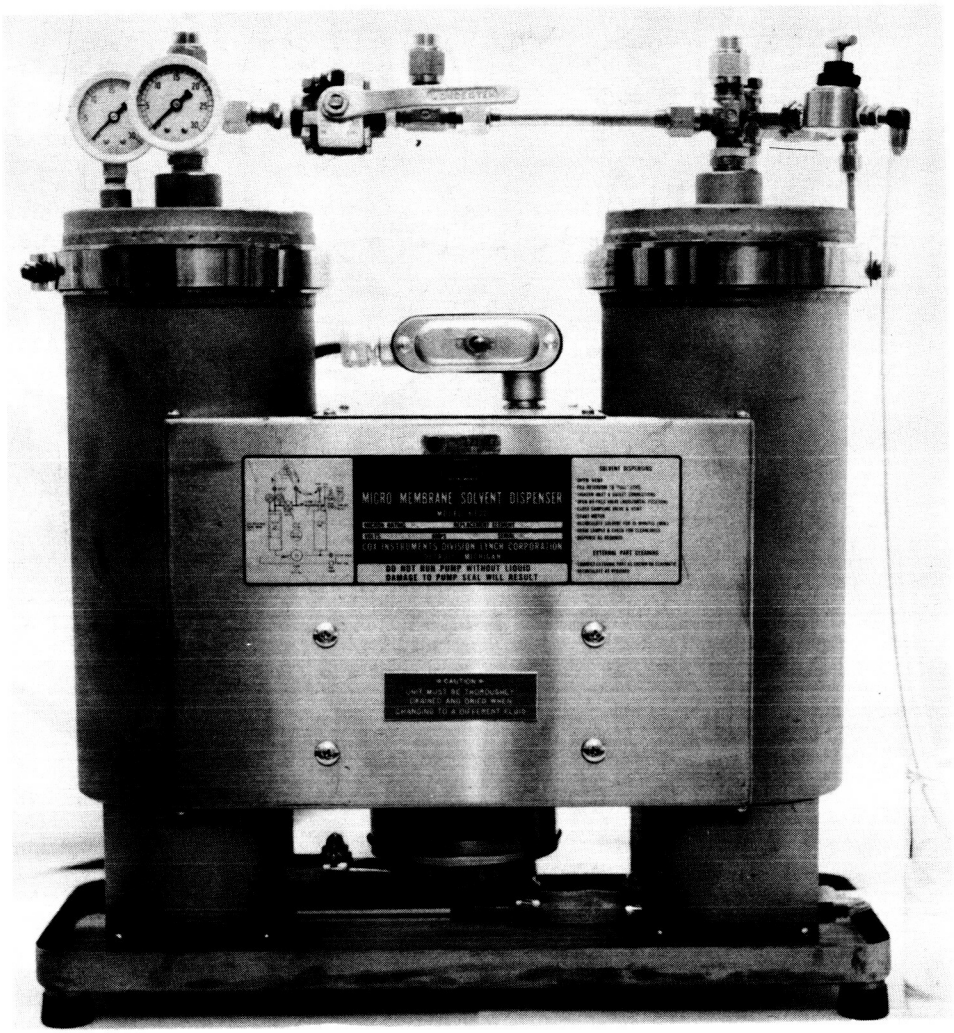


Figure 3–Filtering System for Spore-Contaminated Alcohol

Electronic Component Compatibility with Bactericide - Xylene, as a cleaning agent, and isopropyl alcohol, as a decontaminating agent, were tested to determine their compatibility with the spacecraft electronic components. A summary of these tests is given in Table 3. Prior to conducting these tests, the electronic circuits were electrically checked by the experimenter before any treatment was administered.

After each treatment, prior to conformal coating and encapsulation, the circuits were rechecked to determine the effects caused by the treatment. Environmental tests such as a heat-soak at 65°C for 48 hours and a cold soak at -60°C for 48 hours, were preformed on each of the circuits. The circuits were

Table 3
Summary of Tests and Results on Electronic Components

Unit Nomenclature	No. of Units	Effects of Treatments on Electrical Properties						
		Xylene	Propanol	Conformal Coat	Potting	Heat[1] Soak	Cold[2] Soak	Temperature Cycle[3]
IMP Multiconverter	1	None	None	None	---	None	None	Noisy Zener Diode
Audio Filter[4]	2	None	None	None	None	None	None	None
Incremeg Decade Counter S-049	1	None	None	None	---	---	---	---
2-Bit Binary Circuit	2	None	None	None	None	None	None	None
100 kc Amplifier[5]	1	None	None	None	None	None	None*	Failed*
Incremeg Decade Counter S-060 S-496	2	None	None	None	None	None	None	None
Incremeg Decade Counter S-024	1	None	None	None	None	None	None	None

Notes: (1) Heat soak = held at 65°C for 48 hours.
(2) Cold soak = held at −65°C for 48 hours by means of CO_2 atmosphere
(3) Temperature cycle = 3 hours at 65°C, 1-hour transition time to hold at −65°C for 3 hours, remove and let return to ambient.
(4) Overall frequency shift on filters was less than 1 percent; still flightworthy.
(5) Amplifier now noisy, no further tests.

*Cold-soak temperature and lower temperature of cycle changed to −65°C for this component only.

rechecked after each treatment and subjected to a temperature cycle, i.e., a 3-hour soak at 65°C with a 1-hour transition to -60°C, and soaked at this temperature for 3 hours before returning to ambient room temperature. The results indicated a frequency shift of less than 1 percent on the audio filter circuit, but it was considered usable for flight.

A noisy Zener diode was detected when checking the multiconverter after it had been subjected to the temperature cycle. But, it was also noted that the multiconverter used while conducting the test had been in use in a laboratory for more than one year. The repeated use of the diode could have caused the noise to develop. There was no evidence that indicated that failure had occurred as a result of the decontamination process. It was recommended that in the future the environmental tests be conducted first.

The data in Table 4 were based on a limited number of tests. The average tensile shear strength of the unexposed samples was 1285 psi and was obtained by testing five samples. Only two samples were tested that were first exposed to a half-hour alcohol soak and agitation. The increase in shear stress in Hysol 1-C, Twin-Weld, and Biggs 823 modified possibly occurred because of the thorough cleaning action of the alcohol. It was suggested that a large number of tests should have been performed on samples to obtain additional and more informative data. The reduction in shear strength of Epon 828 was within the design limits, but was not utilized in a critical area in the spacecraft. Samples of other structural materials that were used in the spacecraft were checked for surface microstructure and reflectivity and then agitated in a alcohol soak for one-half hour. Tests were conducted to determine changes in the surface microstructure and reflectivity that were propagated by the alcohol decontamination. Microscopic examinations were made at a magnification of 1200X, and the reflectivity tests were performed over the solar spectrum giving an indication of no changes in any of the samples tested.

Table 4
Average Tensile Shear Strength For a Limited Number of Tests

Nomenclature	Average Tensile Shear Stress	
	Unexposed	1/2 Hour Soak Propanol
Hysol 1-C	1285	1370
Twin-Weld	1520	1690
Epon 828	962	740
Biggs 823 Modified	952	1177

The following summary (Table 5) is based on the absolute differences in the absorptivity of light waves, which occurred between a nondecontaminated control specimen and test specimens which were decontaminated with alcohol or acetone. The change in the absorptivity using alcohol was found to be significant, therefore acetone was considered to be the most desirable. It was noted that when applying either of the solvents to surfaces that were painted white, there was a decrease in solar absorptance. With this change in mind, the Thermal System Branch test conductor recommended that only the buffed and black surfaces be 100 percent decontaminated, these surfaces constituted over 85 percent of the total exposed area of the spacecraft.

Table 5
Thermal Coating Absorptivity Tests

Absolute Deviation from Control Specimen Characteristics		
Coating Description	Effects on Absorptivity	
	Propanol	Acetone
Dow Corning, Methyl Silicone TiO_2	$\Delta\alpha = 0.02$ decrease	$\Delta\alpha = 0.006$ decrease
Cat-A-Lac Black	$\Delta\alpha = 0$	$\Delta\alpha = 0.006$ decrease
Vapor-Deposited Aluminum	$\Delta\alpha = 0.031$ increase	$\Delta\alpha = 0.004$ increase

Note: Absorptivity measurements conducted over entire solar spectrum 0.3 - 2.5 μ

Effectiveness of Spacecraft Decontamination — Two methods of recovering viable organisms remaining on surfaces of decontaminated areas and components were employed to determine the effectiveness of spacecraft decontamination. One method employed control strips with detachable coupons to recover organisms from the electronic circuit module frames (Figure 4). These strips were affixed to each module frame in a manner to simulate typical handling conditions. The control strip proved the effectiveness of the decontaminant and provided a practical method to enumerate the probable viable organisms remaining on the components at each stage of occlusion. The control strips were fabricated from the same material as the printed circuit board in such a manner that five coupons were easily removed. Before each decontamination process – prior to conformal

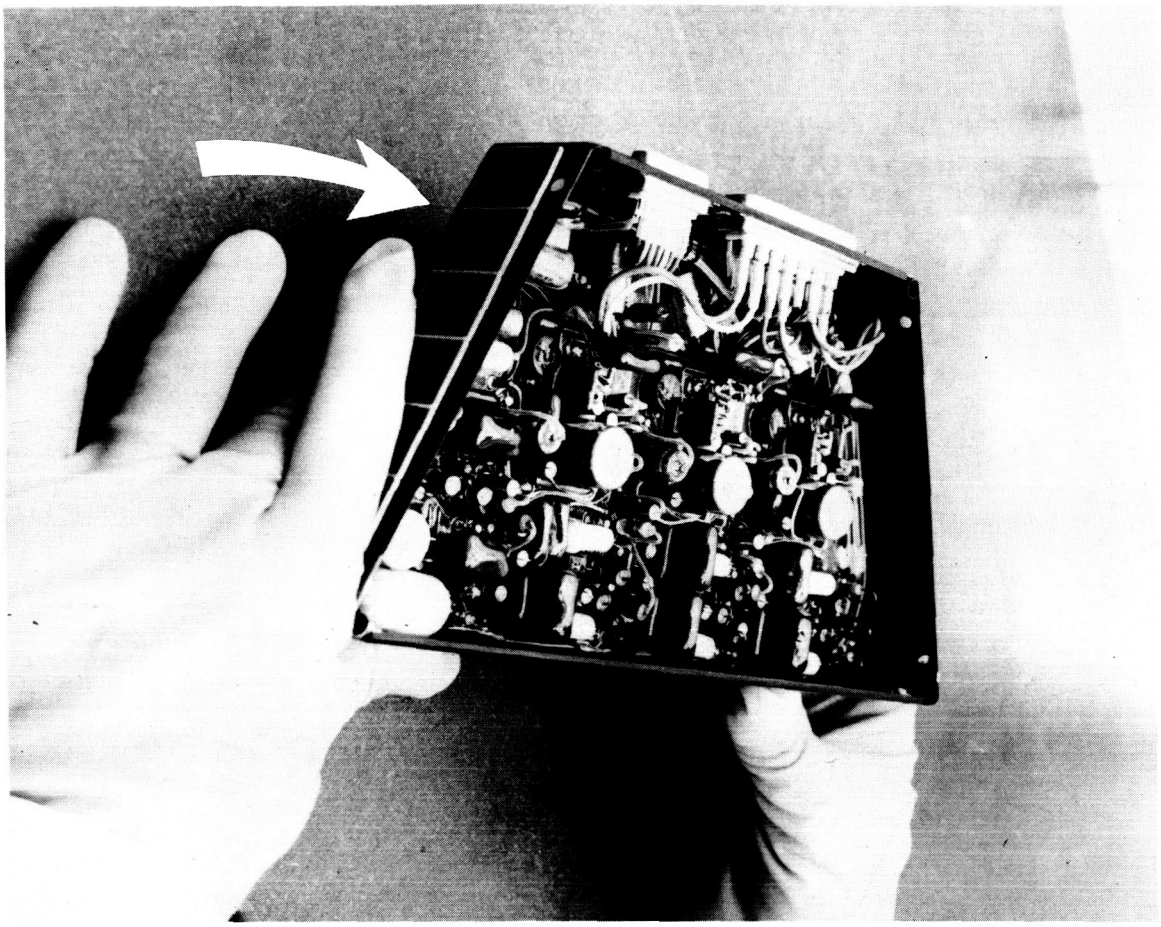


Figure 4–Module with Control Strip and Detachable Coupons

coating, encapsulation, integration, and final assembly — a coupon was removed and assayed to obtain the count of viable organisms. Each decontaminated item and its control strip were processed in the same manner and at the same time. The coupons were placed in a wash bottle containing 15 ml of a 1 percent solution of sterile peptone and shaken with a wrist-action motion for 5 minutes before aliquots of the samples were transferred to pour plates. Two pour plates containing 5-ml aliquots of the contaminated solution were prepared. Also, pour plates with 20 ml of sterile Tryptic Soy Agar (TSA-nutrient) were prepared. All of the plates were incubated at 32°C for a period of 72 hours and then plate counted.

The second method of recovering viable organisms involved sterile swabs, water, and templates that were used to sample surface areas prior to their occlusion by attachments. After taking a sample of the appropriate surface area, each swab was placed in a tube containing 10 ml of sterile distilled water. Each tube was mechanically shaken for 5 minutes. After shaking, 4 ml. aliquots were plated in duplicate and colony counts made. Figure 5 shows such a recovery operation.

mechanically shaken for 5 minutes. After the shaking, 4-ml aliquots were plated out in petri dishes in duplicates and incubated for 72 hours at 32°C. Then the samples were plate counted to determine the number of colony growths obtained. Figure 5 shows the above recovery operation. Figures 6 and 6a depict the areas decontaminated, the manner of decontamination and sterilization, and the method of recovering viable microorganisms.

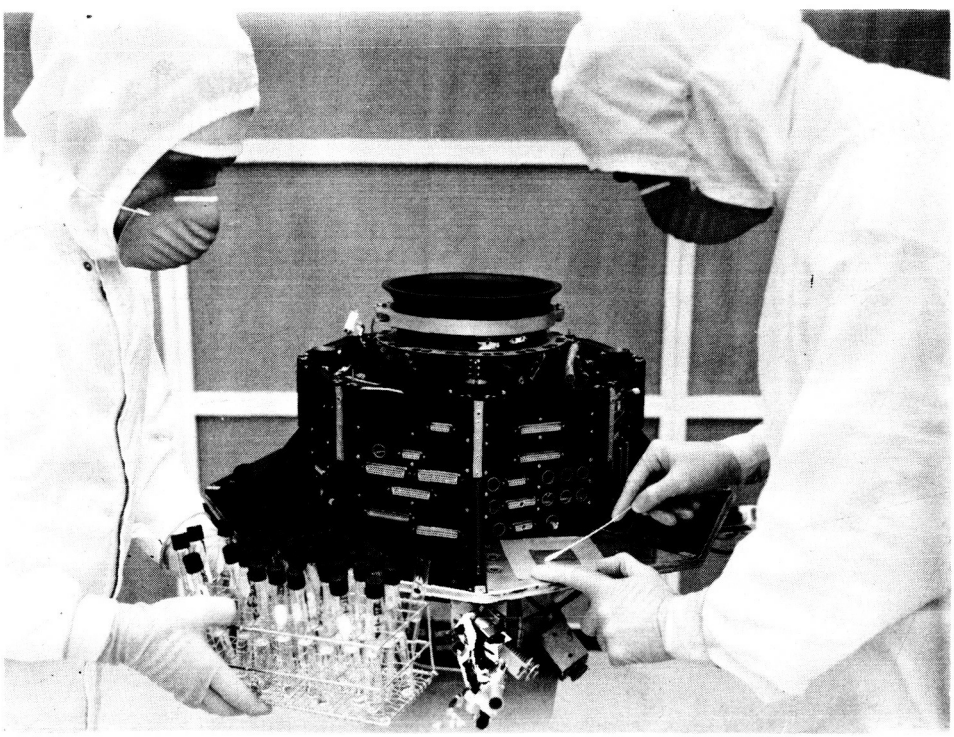


Figure 5–Recovery of Viable Organisms Using Sterile Swab and Template

The electronic modules and control strips were the first component parts of the spacecraft that were decontaminated. They were immersed in 90-percent isopropyl alcohol and agitated at least three times for 15 minutes. A coupon was removed from the control strip and processed for assaying. The electronic circuits were conformal-coated with a bacteriostatic epoxy, and the circuit modules were routed to the laboratory for electrical tests. When the modules were returned to the encapsulation area, they were decontaminated again in the manner previously described, and another decontaminated coupon was removed for assaying purposes; the circuit modules were then encapsulated. Prior to mechanically integrating the module and the spacecraft structure, the area that

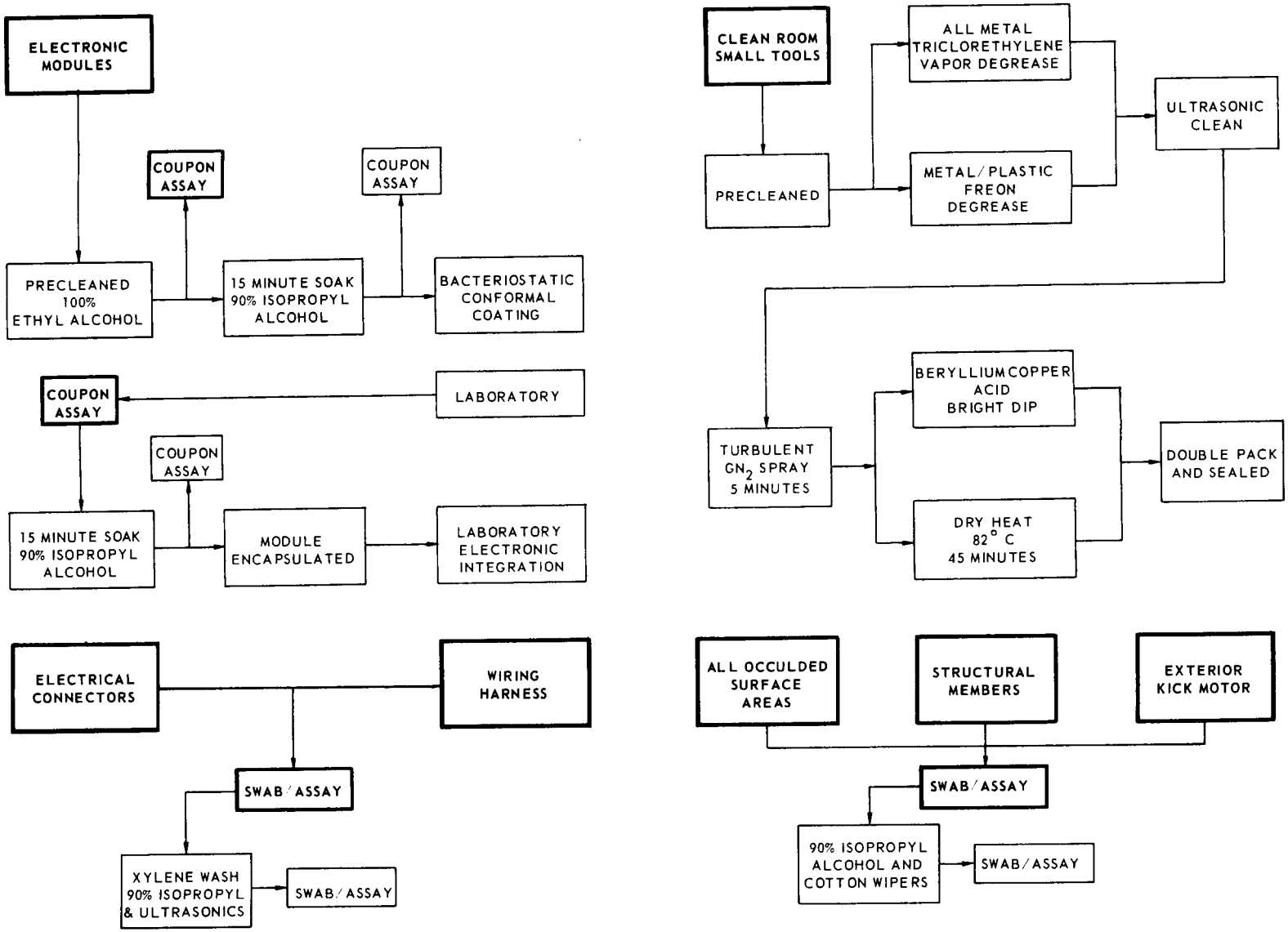


Figure 6–Areas Decontaminated, Manner of Decontamination and Sterilization, and the Method of Recovering Viable Microorganisms

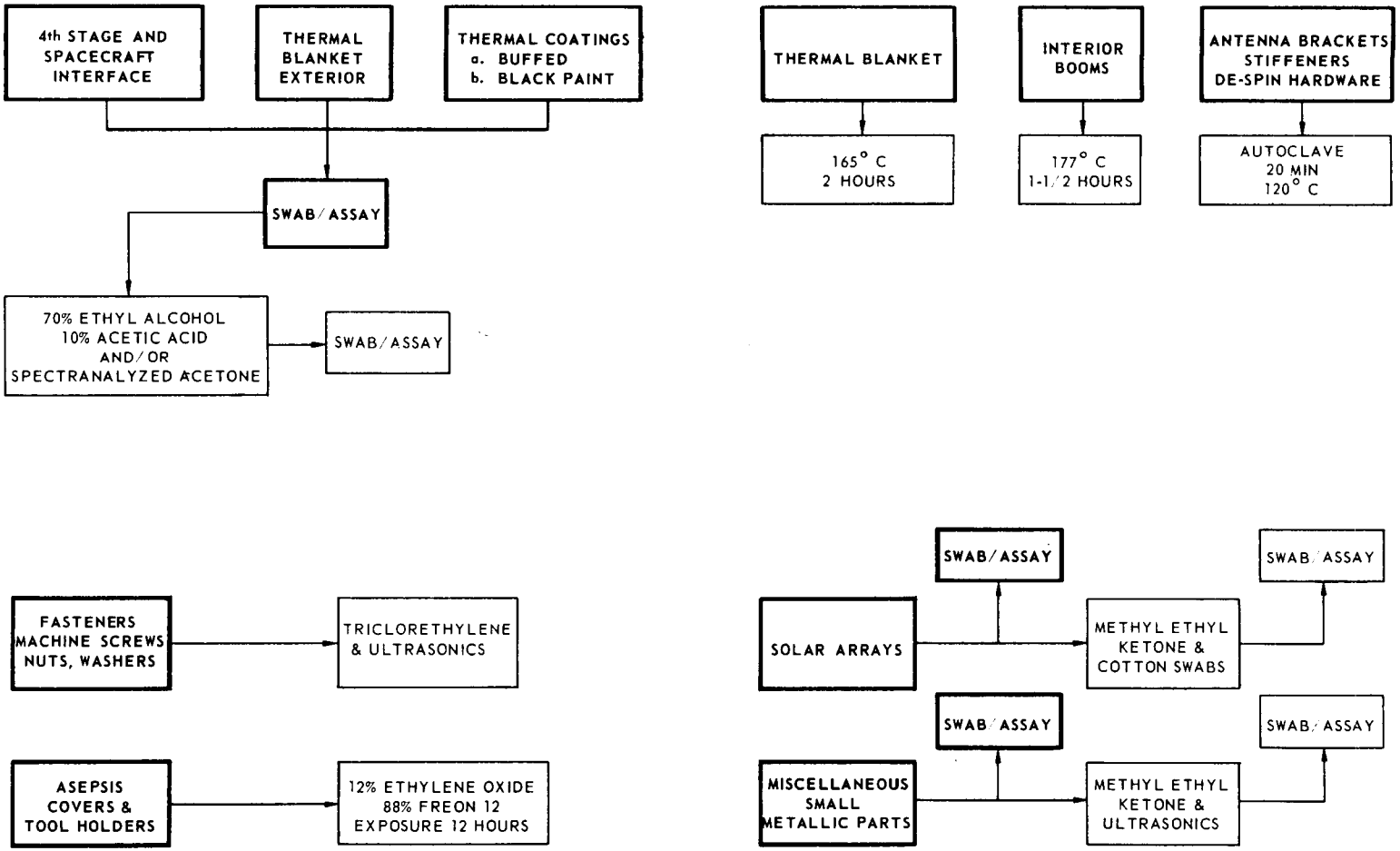


Figure 6–Areas Decontaminated, Manner of Decontamination and Sterilization, and the Method of Recovering Viable Microorganisms

was to be occluded by the module was decontaminated. This area was then sampled by a microbiologist, and assays were performed. After the module was integrated and prior to its occlusion with the top of the cover, all of the exposed surfaces were decontaminated. Samples were again taken, and assayed. The internal burden of the components was estimated and added to the total estimated viable count.

The areas that were occluded by an attachment instrument or structural member were decontaminated, sampled, and assayed. The attachments were integrated, and the exposed surface area was decontaminated. Samples for assays were also taken and treated in the same manner as were the other exposed areas of the spacecraft interior.

It was decided that the greatest source of contamination to a spacecraft was from the technicians and from the generation of debris that occurs during mechanical integration and assembly. It was also determined that clean room facilities should be built that would allow, under aseptic conditions, decontamination of spacecraft components, sampling of areas for assays, mechanical integration, and final assembly.

Figure 7 shows a technician decontaminating the surface of a component that was occluded by an attachment, in the bio-clean area of the clean room complex in the Mechanical Systems Branch at Goddard Space Flight Center. All of the areas mentioned were monitored for microbial contamination and were immediately occluded. The spacecraft was placed on a previously decontaminated dolly approximately 1 foot from the face of the air inlet filter during final decontamination and assembly. All authorized personnel were required to remain "downstream" from the spacecraft at all times while performing any task on, near, or around the spacecraft. The tools that were required during assembly of the spacecraft were sterilized, placed in sterile containers, and routed into the bio-clean area. All personnel that entered the bio-clean area wore lint-free, clean-room garments (sterilized and treated to eliminate static electricity), boots, hood, face mask, and disposable gloves.

Preliminary data (Table 6) pertaining to the decontamination effort were based on contamination detected during the assembly of the spacecraft structure. It related to those areas that were occluded by an attachment, support, or another structural member, and indicated that significant reduction in microbial contamination on a spacecraft system could be obtained. The overall averages of these data, 11,670 micro-organisms per sq. ft. contaminated and 239 micro-organisms per sq. ft. decontaminated, were used to project and estimated microbial burden on the spacecraft at time of launch. These data indicated that the 500 sq. ft. (total area of spacecraft) would have contained 5.8×10^6 micro-organisms before decontamination and would have been reduced to 1.2×10^5 micro-organism at time of launch.

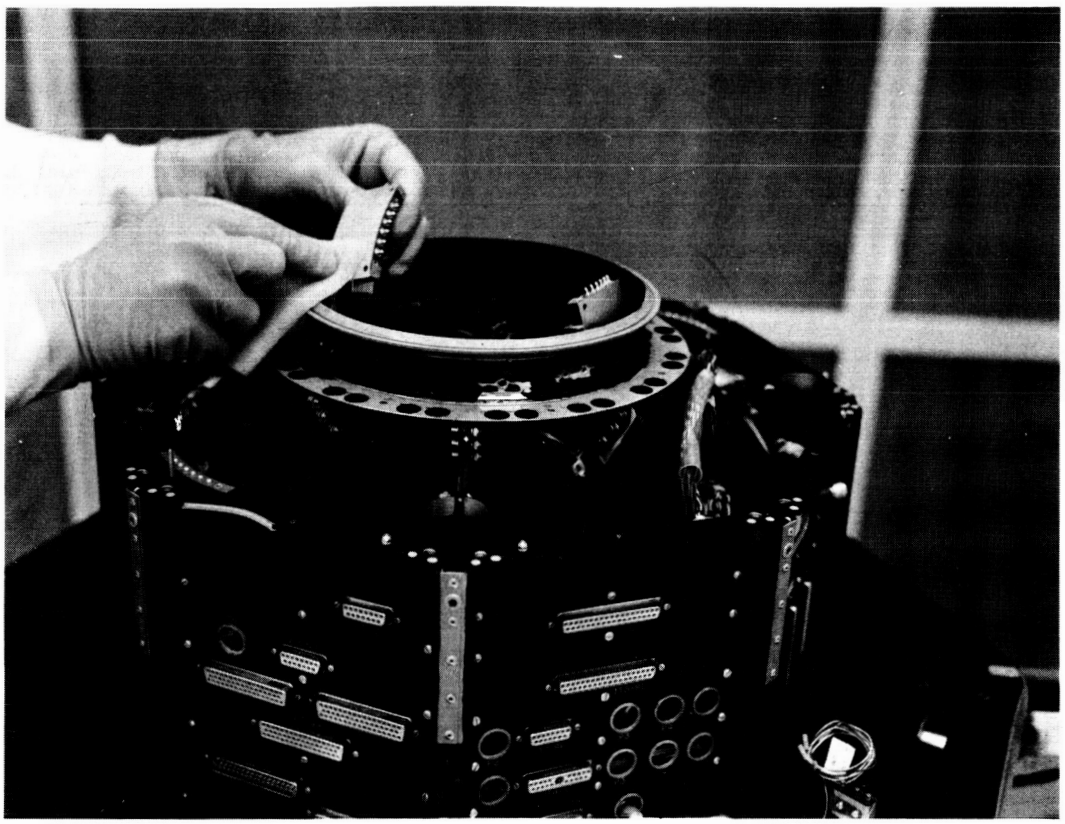


Figure 7–Decontaminating Surface of a Component to be Occluded by an Attachment

Using the method in which the spacecraft was assembled in controlled areas, it is assumed that final assembly and decontamination conducted under aseptic conditions in a class 100 laminar-flow clean room, will result in a further reduction of the microbial load. This assumption is based on a continual natural die-off of vegetative organisms that occur during the elapsed time between sampling and the time of launch.

The decontamination techniques presented in this section were applied at Goddard Space Flight Center. The techniques employed during decontamination of the spacecraft system and the decontaminates used were compatible with spacecraft reliability factors and were in agreement with the Office of Planetary Quarantine, NASA Headquarters.

Clean Room Procedures and Deportment – This section presents a brief description of procedures and clean room deportment for personnel authorized to use the clean room and support decontamination efforts during spacecraft field operations at Kennedy Space Center (KSC).

Table 6
Preliminary Data
Microbial Contamination of AIMP-D Spacecraft

Average Viable Particles Per Sq. Ft.	
Before Decontamination	After Decontamination
21,169	563
22,388	230
1,000	75
2,125	90

The Goddard Down Flow Unit which housed the AIMP-D spacecraft during various tests and experiments was decontaminated and assembled in the airlock, Hi-bay clean room (Figure 8). The procedures employed include the following: decontaminating the spacecraft dolly which also involved removing the strip coating; preparation of ground support equipment (GSE) which entailed removing connecting cables, air inlet filters, all tape and paper units, and filling the voids in instrument racks with cover plates, and replacing air inlet filters with new filter material; and decontaminating electronic equipment connection cables by passing them between two sponges that were soaked in an alcohol solution. Mitocs, telephones, hand tools, and lead pigs that contained radioactive sources were treated in the same manner.

Authorized persons who were conducting tests and experiments or working in any of the clean room areas were subjected to the following partial list of regulations:

- Personnel with respiratory malfunctions, skin ailments, colds, and severe sunburn were not permitted in clean room areas.
- Test fixtures, tools, jigs and assembly fixtures that were necessary to perform specific tasks were permitted.
- No abrasives, e.g., file, crocus cloth, etc., and no shredding or masking tapes.

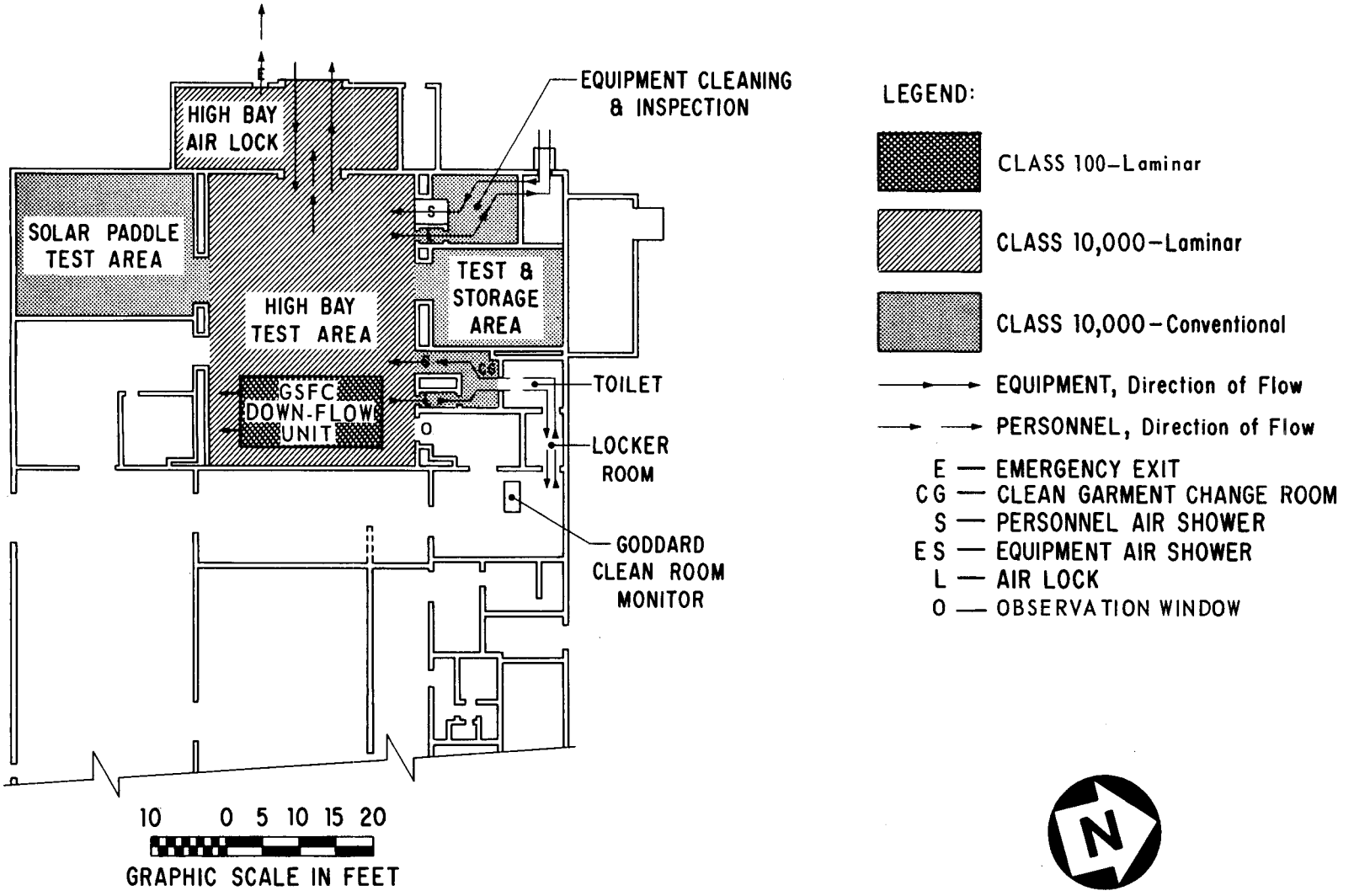


Figure 8–Spacecraft Clean Rooms, Building "AE" KSC

- Exposed parts or components were never left on work benches.
- Approved clean room garments were worn in various clean room areas as previously mentioned.
- Smoking or eating was not permitted.
- Scratching of the head, eyebrows, and other exposed areas of the skin was forbidden.
- Only 10 persons were allowed in the Hi-Bay clean room or any of the other clean room areas at any one time.
- No more than two persons were allowed under the GSFC Down Flow Unit at the same time.
- Hand tools that were not in use were stored in a decontaminating solution.

The clean room regulations as stated above were necessary to assure asepsis handling of the AIMP spacecraft during experiment check-out phases.

The AIMP-D spacecraft was removed from the Down Flow Unit and placed in a container prior to being transported to the spin facility where the kick motor (4th stage) was mated to the payload (AIMP-D). The kick motor interface and the 3rd stage interface was decontaminated, and then a thermal blanket that was previously sterilized was placed over the kick motor.

The solar arrays (flight paddles) were then attached to the body of the payload. The 3rd stage of the vehicle and the spacecraft in a flight configuration were dynamically and staticly balanced as a unit. After the balance tests the paddles were removed and shipped back to the clean room for final decontamination.

The entire unit was then placed in a previously decontaminated container. Prior to this an asepsis cover (sterilized with ethylene oxide compound) was placed over the entire spacecraft. The unit was then transported to the gantry (Pad 17) and placed on the Delta vehicle. The transfer container was removed, but the asepsis cover remained intact over the spacecraft until the air cooling shroud (LOX cleaned and decontaminated with propanol prior to going to the gantry for assembly) was assembled and put into operation. Verification that the filtered air was Class 100 was authenticated by chemical engineers from PAN AM, at KSC. The filtered air entered from the top of the cooling shroud, was temperature controlled and passed through a diffuser designed to assimilate a verticle laminar flow of air over the spacecraft. The sides of the clean air

"coolie hat" shroud were rolled up to permit mating of the nose cone fairing which was fitted to the Delta vehicle. During this operation the asepsis cover remained on the spacecraft to protect it from particulate matter. During this operation the flow of air was continued and the sides of the shroud were let down after the fitting. The nose cone fairing was moved back but remained under the clean air cooling shroud.

The paddles were decontaminated with methyl ethyl ketone (MEK) and placed into containers that were previously decontaminated with propanol. Prior to launch the asepsis cover and all of the protective stripable coatings were removed. All exposed surfaces were then decontaminated.

The thermal coatings were decontaminated with triple distilled acetone, spectralanalyzed grade. However, all stubborn deposits were first removed with a 10 percent acetic acid solution and 70 percent ethanol; all other exposed areas were decontaminated with propanol. Prior to installation of the solar arrays, all mating surfaces were decontaminated and the paddle tie down cords were affixed.

All representative areas were biologically sampled so that assays could be performed to determine the biological load before launch.

All of the gantry operations as well as clean room operations at KSC throughout the entire program were monitored by the NASA Sterility Control Officer (Jack H. Fooks). The GSFC Down Flow Unit and the surrounding areas in the KSC clean room were monitored by personnel from the Sterility Control Laboratory, operated for NASA by the U.S. Public Health Service, Phoenix, Arizona, operated at KSC for NASA by Gerry Tritz.

The nose cone fairing was previously decontaminated and LOX cleaned by Douglas Aircraft Corporation (DAC) personnel, and then mated to the vehicle containing the payload. The filtered conditioned air umbilical was then connected to the nose cone fairing and the spacecraft was constantly bathed with class 100 air until separation of the umbilical at launch.

After all of the bio-samples were taken those areas were re-decontaminated to assure that no nutrients were being carried into space.

A diagram (Figure 9) depicts operations that were performed at GSFC and KSC from the initial starting point of the decontamination efforts and assembling of the spacecraft to final bio-sampling.

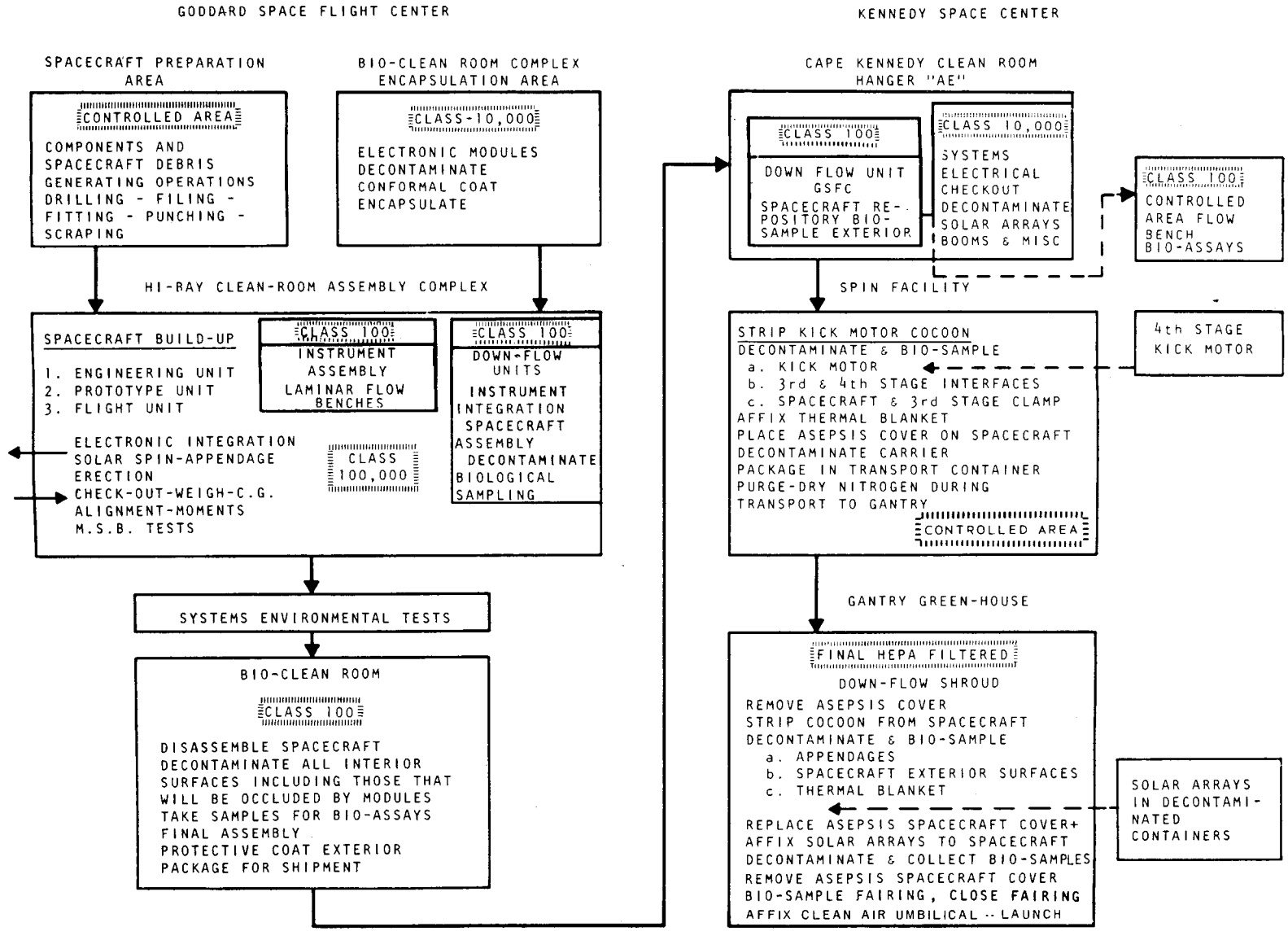


Figure 9—Diagram of Spacecraft Operations at GSFC and KSC

MICROBIOLOGICAL BURDEN ON THE SURFACES OF THE AIMP-D SPACECRAFT

All surfaces of the spacecraft were monitored for microbiological contamination prior to occlusion. Figure 10 shows the spacecraft surfaces that were sampled. These surfaces included the mating platform for the C-frame, the C-frame base, the mating platform surface for the lower support ring, and the lower cone-support ring.

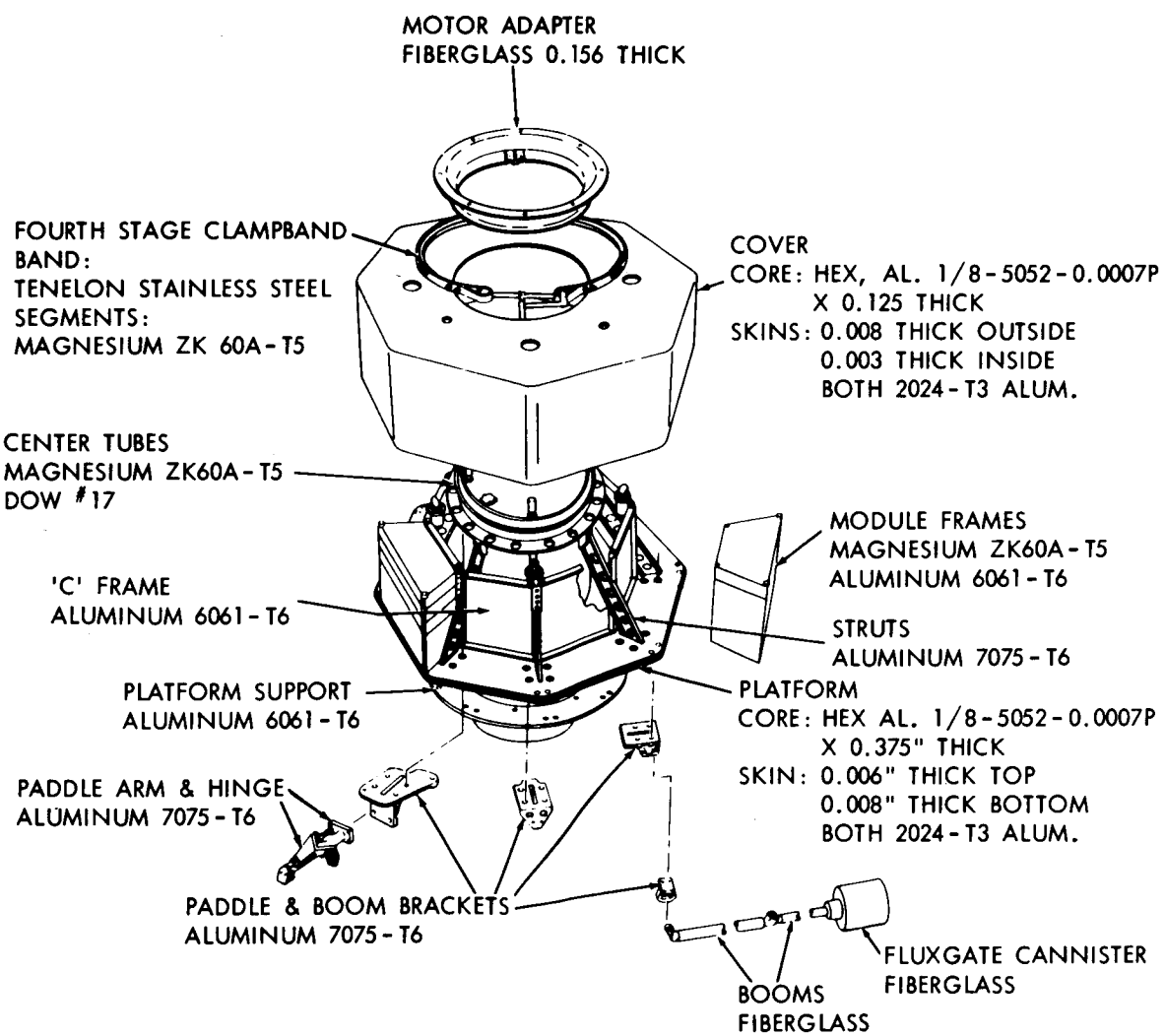


Figure 10–AIMP-D Spacecraft Showing Spacecraft Configuration and Structural Materials

Sampling Procedure — Sterile cotton swabs wetted with sterile distilled water were used to sample surfaces of the spacecraft. Screw-cap tubes containing 10 ml of distilled water were sterilized by autoclaving for 15 minutes at 121°C. Cotton swabs were sterilized for 30 minutes at 121°C.

Prior to sampling, a swab was inserted into a tube of distilled water and moistened. Excess water was removed by pressing the swab on the inside wall of the tube with a twisting, rolling motion. Quantitative data were obtained by sampling a 4-square-inch area outlined by sterile kraft paper templates. Some of the templates were prepared to fit the configuration of the spacecraft; for this reason, some had sampling areas measuring 1 by 4 inches and some 0.5 by 4 inches. The swab was aseptically broken off into a tube of sterile distilled water. Each tube was mechanically shaken for 5 minutes on a gyro-rotary shaker followed by a vigorous manual shaking for 2 minutes. This procedure dispersed the cotton into the water. Then 4-ml aliquots were plated out in duplicate into sterile, disposable petri dishes containing 20-ml aliquots of TSA.

Culturing normally occurred within 1 hour after breaking off the swab in the tube of distilled water. All plates were mixed by a swirling motion and then incubated.

Microbial Fallout — Microbial fallout on stainless strips was determined by Gerald Tritz, U.S. Public Health Service, Cape Kennedy, Florida. Trays of stainless steel strips (1 by 2 inches) were positioned on one side of the laminar crossflow, class 10,000 clean room, upstream and downstream from personnel and midway of the clean room; one tray was placed in the downflow clean room (Class 100). Six strips were recovered once a week from each location and assayed for aerobic and anerobic vegetative and spore cells.

Air Sampling — Air samples were collected in the morning and afternoon, using Reyneir slit samplers with a 1-hour clock. Air was drawn into the samplers at a rate of 1 cubic foot per minute for 60 minutes. Glass plates (150 by 20 mm) containing 60 ml of TSA were used in the samplers. Air samplers were placed approximately at bench-top level (3 feet above the floor) in three different positions, upstream, in the downflow room, and downstream.

Table 7 lists the microbiological contamination in the air of the clean rooms which housed the AIMP-D Spacecraft during field check out tests, as well as the number of personnel in the room during the sampling period. The counts in both rooms were extremely low, which makes it difficult to generalize. However,

Table 7
Microbial Contamination in the Air of Laminar-Flow Clean Rooms Housing the AIMP-D Spacecraft
(viable particles/cubic foot)

Day*	Downflow Room				Crossflow Room Upstream				Crossflow Room Downstream			
	AM		PM		AM		PM		AM		PM	
	Count	No. Personnel	Count	No. Personnel	Count	No. Personnel	Count	No. Personnel	Count	No. Personnel	Count	No. Personnel
1 (Fri)	0	1-2	0.01	1-2	0.05	6	0.05	9	0.2	6	---	---
4 (Mon)	0	0-1	0	0-1	0	3-4	0.01	6-8	0.01	3-4	0.05	6-8
5 (Tues)	0	0-2	0	0-2	0	6-8	0.05	5-8	0.06	6-8	0.08	5-8
6 (Wed)	0	0-2	0	0-1	0.01	3-5	0	4-8	0	3-5	0.08	4-8
7 (Thurs)	0	0	0	0	0	3-6	0	4-8	0	3-6	0.05	4-8
8 (Fri)	0	0-1	0	0	0	1-4	0.01	2-7	0.05	1-4	0.08	2-7
11 (Mon)	0	0	0	0	0	0-2	0	1	0.016	0-2	0	1
12 (Tues)	0	0	0	0	0	1-3	0.013	1	0.033	1-3	0.033	1
13 (Wed)	0.013	0	0	0	0	1-2	0	1-2	0	1-2	0	1-2
14 (Thurs)	0	0	0	0	0	0-1	0	0-1	0	0-1	0	0-1
15 (Fri)	0	0	0	0	0	0-1	0	0	0	0-1	0	0
Average Viable Particles/Ft^3	0.0012		0.0009		0.0055		0.0120		0.0335		0.0348	

*June 3 – June 17, 1966

the data indicated that counts were lowest in the downflow room which was not as heavily populated. Counts from the crossflow room were lower upstream than they were downstream. Because the spacecraft was transferred to the gantry on the twelfth day, the rooms were relatively unoccupied during the last four days except for cleaning. It is interesting to note that counts were lowest downstream in the crossflow room during the last four days; personnel appeared to have little or no influence on the upstream air.

Table 8 presents a microbiological profile of the air in two clean rooms during two typical work days. Samples were collected every hour for seven hours. Lunch period occurred during the fourth hour on day 1, whereas it occurred during the third hour on day 2.

Table 9 lists the microbiological fallout on stainless steel strips over a 4-week period. Only aerobic vegetative cells were detected in the downflow room after one and three weeks of exposure. Aerobic spores detected after three weeks of exposure were the only microorganisms isolated upstream in the crossflow room. Aerobic and anaerobic vegetative cells, and aerobic and anaerobic spores, were detected after one and three weeks of exposure downstream in the crossflow room, respectively. From the center of the crossflow room, anaerobic spores and aerobic vegetative cells were detected after one and three weeks, respectively.

CONCLUSIONS

It was concluded that on the basis of the microbial records of typical sampled surface areas, the number and size of these areas, component manufacturing methods, and environment control after decontamination, the Office of Planetary Quarantine, NASA Headquarters, determined that the orbiting AIMP-D spacecraft contained no more than 4.04×10^6 viable organisms prior to decontamination and 1.5×10^5 organisms after decontamination. An additional reduction in numbers of viable microorganisms had occurred during the 45 day period between initial decontamination and launch as a result of natural die-off; this places the estimated total at 1.5×10^4 organisms. Assuming a successful orbit with a life expectancy of 180 days and 240 temperature cycle changes between -45°C and +50°C in an ultrahigh vacuum it was determined by the Office of Planetary Quarantine that further die-off between launch and lunar impact would reduce the number of microorganisms available for release on the lunar surface to an estimated 1×10^3 sporulative microorganisms.

Table 8
Microbial Contamination in the Air of Laminar-Flow
Clean Rooms Over a 7-Hour Period

Hour	Viable Particles per Cubic Foot							
	Downflow Room				Crossflow Room Downstream			
	Day 1(5-26-66)		Day 2* (5-19-66)		Day 1(5-26-66)		Day 2* (5-19-66)	
	Count	Personnel	Count	Personnel	Count	Personnel	Count	Personnel
1	0.033	0	---	---	0.016	0-5	0.016	0-8
2	0	0-2	---	---	0.033	4-8	0.016	0-7
3	0	0-1	0.05	0	0	4	0	0
4	0	0	---	---	0.016	0-3	0.016	0-2
5	0	0-2	0.016	0	0.066	0-8	0.050	0
6	0	0-2	0	0	0.100	8	0.033	0
7	0	0-1	---	---	0.050	4-7	---	---
Average Viable Particles/Ft^3	0.0047		0.0220		0.0401		0.0218	

*Courtesy of Gerald Tritz, U.S. Public Health Service, Cape Kennedy, Florida

Table 9

Microbial Fallout on Stainless Steel Strips*

Week of Exposure	Viable Organisms per Square Foot															
	Downflow Room				Crossflow Room											
					Upstream				Center				Downstream			
	Vegetative Cells		Spores		Vegetative Cells		Spores		Vegetative Cells		Spores		Vegetative Cells		Spores	
	Aerobic	Anaerobic	Aerobic	Anaerobic	Aerobic	Anaerobic	Aerobic	Anaerobic	Aerobic	Anaerobic	Aerobic	Anaerobic	Aerobic	Anaerobic	Aerobic	Anaerobic
1	57	0	0	0	0	0	0	0	0	0	0	57	29,016	57	0	0
2	0	0	0	0	–	–	–	–	–	–	–	–	–	–	–	–
3	120	0	0	0	0	0	57	0	122	0	0	0	0	0	360	360
4	–	–	–	–	0	0	0		0	0	0	0	0	0	0	0

*Courtesy of Gerald Tritz, Public Health Service, Cape Kennedy, Florida

Table 10
Final Microbial Count of Total Area of Spacecraft

TOTAL AREA OF SPACECRAFT 526 SQ. FT.	
CONDITION	VIABLE MICROORGANISMS
Contaminated	4.04×10^6
Decontaminated	1.50×10^5
Natural die-off 45 days	1.50×10^4
Assumed 180 days life orbit at -45° +50°C 240 temperature cycles	1.50×10^3

As a result of conducting the Decontamination effort on the AIMP-D spacecraft the following conclusions were made.

1. The solar paddles on the AIMP-E spacecraft will not be decontaminated with methyl ethyl ketone. They will be decontaminated with a 90% solution of propanol and a finish wipe with 85% ethanol.

2. After taking the bio-samples with sterile swabs from the decontaminated spacecraft AIMP-E the sampling swabs will be placed in a test tube containing 5 ml of sterile 1.0% peptone water solution.

3. A second decontamination will be made of the areas sampled so as to remove any nutrient deposited by swabs in sampling which may have remained on the surfaces sampled.

4. The following deviations from the AIMP-D sampling and assaying will be employed on the AIMP-E spacecraft.

   a. Test tubes containing contaminated swabs will be placed into an ultrasonic bath (25 kc/sec) for 12 minutes.

   b. Two (2) 100 mm-diameter petri dishes will be prepared each containing 1.0 ml of the ultrasonicated nonheat-shocked sample solution and 20 ml of sterile trypticase soy agar.

   c. Remaining portion of the contaminated and ultrasonicated sample solution will be heat shocked in water bath at 80°C for twenty minutes.

d. Two (2) 100 mm-diameter petri dishes will be prepared each containing 1.0 ml of heat-shocked sample solution and 20 ml of trypticase soy agar.

e. One (1) nonheat-shocked sample and one (1) heat-shocked sample from each swab assay will be aerobically incubated. Colony counts will be made on the aerobically incubated plates after 24, 48, and 72 hours.

f. The remaining nonheat-shocked and heat-shocked sample petri dishes will be anaerobically incubated. Colony counts will be made after 72 hours of incubation. All samples will be incubated at 32°C.

g. Bio-records will indicate the number each of aerobic viable microorganisms, vegatative and sporulative and anaerobic viable microorganisms, vegatative and sporulative.

The author states that to his knowledge this is the first attempt made to measure microbiological contamination of an entire spacecraft system during the phases of mechanical integration, assembly, systems testing and launch. The knowledge gained and techniques developed in carrying out the decontamination program may be applicable in developing sterilization techniques for future interplanetary spacecraft and landing capsules.

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APPENDIX A

LIST OF MATERIALS FOR AIMP MECHANICAL STRUCTURES

Dwg. no.	Dwg. title	Material	Description
GE-IMP(D)-1986	Structural ass'y		Loctite, grade B (7-2) yellow (screws, stainless steel-non magnetic)
GE-IMP(D)-1742	Center support, -lower half	Magnesium ZK 60A-T5	Heli-coil-1191-3-BN-164; dow 17 surface coating, 0.0005 thk. (Threaded insert)
GE-IMP(D)-1743	Center support, -upper half	Magnesium ZK 60A-T5	Heli-coil-1191-3 BN-190; nut-anchor - LHTA-3452.62; rivet 100° flat hd. 3/32 dia. × 1/8 lg. al. alloy, Dow 17 surface coating, 0.0005 thk.
GE-IMP(D)-1705	Shelf Assembly	Alum. alloy	Alum. alloy 6061-T6; al. honeycomb 5052-H39; al. foil 2024-T3; Delron fasteners, alum. anodized (surface treatment to 4-1/2)
F-IMP(D)-1895	Paddle arm bracket	Alum. alloy 7075-T6	Buffed surface to $^{8}\mu$ inches (finish)
GO-IMP(D)-1879	Fluxgate boom bracket	Alum. alloy 7075-T6	Buffed surface to $^{8}\mu$ inches (finish)
GO-IMP(D)-1878	Strut support	Alum. alloy 7075-T6	Buffed surface to $^{8}\mu$ inches (finish)
GD-IMP(D)-1748	Strut	Alum. alloy 7075-T5	Anodized clear, MIL-A-8625, type II. (Surface treatment)
GC-IMP(D)-1799	Shoulder screw	St. stell 304	---
GD-IMP(D)-2012	Arm and hinge assembly	---	Nut. hex. al. alloy; rd. hd. screw. al. alloy; transistor, no. 2N1724/1

Dwg. no.	Dwg. title	Material	Description
GD-IMP(D)-1913	Paddle arm	Alum. alloy 7075-T6	Anodized clear, MIL-A 8625, type II.
GD-IMP(D)-1875	Main Hinge	Alum. alloy 7075-T6	Anodized clear, MIL-A-8625, type II.
GC-IMP-1183	Stop plug spring	Elgiloy	Wire dia. 0.031 (Special type of wire, non-mag.)
GC-IMP-1190	Stop plug pin	Alum. alloy 7075-T6	Anodized clear, MIL-A-8625, type II.
GC-IMP-1690	Stop plug	Alum. alloy 7075-T6	Anodized clear, MIL-A-8625, type II; emrolon coating 0.002 thk.
GC-IMP-1185	Elevation spring	Elgiloy	Wire dia. 0.094 (Special type wire, non-mag.)
GC-IMP-1196-2	Washer	Alum. alloy 6061-T6	Anodized clear, MIL-A-8625, type II; emrolon coating, 0.002 thk.
GC-IMP-1189	Main hinge pin	Alum. alloy 7075-T6	Anodized clear, MIL-A-8625, type II; emrolon coating, 0.002 thk.
GC-IMP-1187	Elevation spring bracket	Alum. alloy 6061-T6	Anodized clear, MIL-A-8625, type II; emrolon coating, 0.002 thk.
GC-IMP-1329	Washer	Teflon	
GC-IMP-1303	Housing	Alum. alloy 7075-T6	Anodized clear, MIL-A-8625, type II, emrolon coating, 0.002 thk.

Dwg. no.	Dwg. title	Material	Description
GE-IMP(D)-1923	Solar paddle Structure ass'y	Alum. alloy and Fiber-glass	Alum. alloy 6061-T6, 6061-T4; al. honeycomb 5052-H39; fiberglass cloth, #108; expanded metal, silver .002 thk.; bus bar copper 5 mil thk. silver plated; screw fillister hd oval, st. steel-non-mag.; nut-hex light 68-NM-04; knuckle 7075-T6; contact block, glass cloth, grade G-11, epoxy-epon 828; solder terminal-turret, No. 1597-1; grom-met, silicone rubber, type SE-452; soft solder-mat'l. QQ-S-571; anodize clear, MIL-A-8625, type II, adhesive EM 1000, per MPS-PR-115, MIL-A-5090D, type I.
GE-IMP(D)-1814	Cover assembly	Alum. alloy	Alum. alloy 6061-TG; al. honeycomb 5052-H39; al. foil 2024-T3; magnesium ZK 60, adhesive-FM1000, per MPS-PR-115, MIL-A-5090D, type I.
GF-IMP(D)-1942	Motor adapter	Glass cloth	Fabric style 181 glass/cloth, Epon 828
GF-IMP(D)-2030	Clamp band ass'y	---	Screw, long-lok no. LL33M6255(special self locking screw)
GD-IMP(D)-2036	Band	St. steel 414	Finish-passivate; rivet M520426B3-5; rivet MS20470DD4-4
GD-IMP(D)-1864	Band	St. steel 414	Finish-passivate; rivet MS2042683-5; rivet MS20470DD4-4
GC-IMP(D)-2028	End pin	Alum. alloy 7075-T6	Anodize clear, MIL-A-8625, type II.
GC-IMP(D)-2029	End pin	Alum. alloy 7075-T6	Anodize clear, MIL-A-8625, type II.
GC-IMP(D)-2032	Spring	Beryllium copper	Berylco 25, QQ-C-533 (non-magnetic material)
GC-IMP(D)-1870	Spacer	Alum. alloy 6061-TG	Anodize clear, MIL-A-8625, type II.
GC-IMP(D)-1883	Screw	Holo-krome	---

Dwg. no.	Dwg. title	Material	Description
GC-IMP(D)-1876	Segment	Magnesium ZK60A-T5	Dow 17 surface coating, 0.0005 thk.
GC-IMP(D)-2038	Segment	Magnesium 2K604-T5	Dow 17 surface coating, 0.0005 thk.
GC-IMP(D)-1865	Washer	Alum. alloy 6061-T6	Anodize clear, MIL-A-8625, type II.
GC-IMP(D)-2035	Key	Magnesium ZK60A-T5	Dow 9 surface coating, 0.0005 thk.
GD-IMP(D)-2044	Antenna assembly	---	Screw, long-lok no. LL44U62J6; screw, long-lok no. 44D2654; braze mat'l, allstate 31
GD-IMP(D)-1793	Cup	Alum. alloy 6061-T6	---
GC-IMP(D)-1825	Insert	Fluorosint No. 3	---
GC-IMP(D)-1790	Terminal	Copper, hard	---
GC-IMP(D)-1794	Disc	Alum. alloy 6061-T6	---
GC-IMP-1092	Antenna stub pin	Alum. alloy 7075-T6	---
GC-IMP(D)-1826	Elbow	Alum. alloy 6061-T6	Nickel flash plating
GC-IMP(D)-1817	Tube base	Alum. alloy 6061-T6	---
GC-IMP(D)-2046	Base tube	Alum. alloy 6061-T6	---
GC-IMP(D)-2045	End tube	Alum. alloy 6061-T6	---
GC-IMP-1100	Cap	Alum. alloy 6061-T6	---
GC-IMP(D)-1850	Connector (male) assembly	---	---
GC-IMP(D)-1842	Connector (male)	Glass fibre	Diallyl phthalate-glass fibre filled, per MIL-M-19833, type GD1-30
GC-IMP(D)-1843	Spring	Beryllium copper	QQ-C-530, 1/2 hard (non-magnetic)

Dwg. no.	Dwg. title	Material	Description
GC-IMP(D)-1848	Retaining ring	Teflon	MIL-P-19468A
GC-IMP(D)-1837	Contact pin	Brass comp.	24 HH, per QQ-B-613; silver plate 0.0002 thk., QQ-5-365; gold plate 0.0001, MIL-G45204
GC-IMP(D)-1841	Connector (female)	Glass fibre	Diallyl phthalate-glass fibre filled, per MIL-M-19833, type GD1-30
GC-IMP(D)-1869	Insert	Alum. alloy 6061-T6	Anodize clear, MIL-A-8625, type II.
GC-IMP(D)-1836	Contact pin	Brass comp.	24 HH, per QQ-B-613; silver plate 0.0002 thk., QQ-S-365; gold plate 0.0001, MIL-G-45204
GC-IMP(D)-2001	Insert	Alum. alloy 6061-T6	Anodize clear, MIL-A-8625, type II.
GC-IMP(D)-1872	Shield	Copper	Gold plate, MIL-G-45204, type II, class 2
GC-IMP(D)-1871	Shield	Copper	Gold plate, MIL-G-45204, type II, class 2
GE-IMP(D)-1861	Battery can ass'y	---	Epoxy-epon 834; connectors-DAF-15 S(R); DBF-25S(R) battery silcad YS11
GE-IMP(D)-1855	Battery can	Magnesium ZK60A-T5	Dow 17 surface coating, 0.0005 thk.
GC-IMP(D)-2020	Guide pin	Alum. alloy 6061-T6	Anodize black, MIL-A-8625, type II.
GC-IMP(D)-1860	Cell contact strip (large)	Copper	Silver plate, MIL-STD-171, finish 1.7.3.
GC-IMP(D)-1859	Cell contact strip	Copper	Silver plate, MIL-STD-171, finish 1.7.3.
GC-IM(D)-1900	Battery bolt	St. steel 304	Passivate, MIL-STD-171, finish 5.4.1
GD-IMP(D)-1984	Thermal shield	Alum. alloy 6061-T6	Anodize black, MIL-A-8625, type II; rivet MS20470DD2-3; nut LATA51M2860-40
GD-IMP(D)-1992	Spring seat disk	Alum. alloy 6061-T6	Buffed surface to[8]

Dwg. no.	Dwg. title	Material	Description
GD-IMP(D)-1745	Heat shield	Fiberglass	Glass cloth #108
GD-IMP(D)-1991	Spring seat ring	Alum. alloy 6061-T6	Buffed surface to[8]
GC-IMP(D)-2024	Screw, tie down	Alum. alloy 6061-T6	Martin hardcoat
GC-IMP(D)-1930	Circuit board	Fiberglass	MIL-P-13949-GE-062-C1
GC-IMP(D)-1750	Cross bar	Magnesium ZK60A-T5	Dow 17 surface coating 0.0005 thk.
GD-IMP(D)-1929	Circuit board	Fiberglass	MIL-P-13949-GE-062-C1
GF-IMP(D)-1751	Module support Frame type C	Alum. alloy 6061-T6	Anodized black, MIL-A-8625, type II.
GC-IMP(D)-1980	Front corner tie-in	Alum. alloy 6061-76	Anodized black, MIL-A-8625, type II.
GE-IMP(D)-2047	Transmitter	Magnesium ZK60A-T5	Surface coating, MIL-M-3171, type IV. (Dow 9)
GD-IMP(D)-2048	Transmitter cover, bottom	Magnesium ZK60A-T5	Surface coating, MIL-M-3171, type IV. (Dow 9)
GD-IMP(D)-2049	Transmitter cover, top	Magnesium ZK60A-T5	Surface coating, MIL-M-3171, type IV. (Dow 9)
GE-IMP(D)-2080	Range and range rate no. 1	Magnesium ZK60A-T5	Surface coating, MIL-M-3171, type IV. (Dow 9)
GE-IMP(D)-2081	Range and range rate no. 3	Magnesium ZK60A-T5	Surface coating, MIL-M-3171, type IV. (Dow 9)
GE-IMP(D)-1949	Programmer no. 1	Alum. alloy 6061-T6	Anodize black, MIL-A-8625, type II, rivet-pop, AD31ABS; nut-anchor, LHTA 3300-40
GE-IMP(D)-2015	Cosmic dust experiment	Alum. alloy 6061-T6	Anodize black, MIL-A-8625, type II, rivet-pop, AD31ABS; nut-anchor, LHTA 3300-40

Dwg. no.	Dwg. title	Material	Description
GD-IMP(D)-1950	Separation switch assembly	---	Retaining ring, 5100-18C; Micro Switch JE-5; rivet MS20470DD2-14, Micro Switch ISEI-T; long-lok LL33M26514; nut MS21043-04
GC-IMP(D)-1928	Switch bracket	Magnesium ZK60A-T5	Surface coating MIL-M-45202, type I, class C, 0.0005 thk.
GC-IMP(B)-1739	Spring	Beryllium copper	QQ-C-530, 1/2 ht
GC-IMP(D)-1919	Actuator shaft	Alum. alloy 6061-T6	Anodize clear, MIL-A-8625, type II.
GC-IMP(D)-1920	Cam shaft	Alum. alloy 6061-T6	Anodize black, MIL-A-8625, type II.
GC-IMP(D)-1840	Roller	Alum. alloy 6061-T6	Anodize clear, MIL-A-8625, type II.
GC-IMP(D)-1936	Separation mech. assembly	---	Screw, long-lok LL33V40H4 and LL33D2654
GD-IMP(D)-1931	Housing	Alum. alloy 6061-T6	Anodize clear, MIL-A-8625, type II.
GC-IMP(D)-1932	Pin	St. steel 303	MIL-W-52263
GC-IMP(D)-1933	Spring	Beryllium copper	QQ-C-530, 1/2 ht
GC-IMP(D)-1934	Spring cap	Alum. alloy 6061-T6	Anodize clear, MIL-A-8625, type II; emrilon teflon coating 0.001 thk.
GC-IMP(D)-1935	Spring cap	Alum. alloy 6061-T6	Anodize clear, MIL-A-8625, type II.
GC-IMP(D)-1947	Pad	Alum. alloy 6061-T6	Anodize clear, MIL-A-8625, type II.
GC-IMP(D)-2056	Pad	Alum. alloy 6061-T6	Anodize clear, MIL-A-8625, type II.
GC-IMP(D)-2057	Leaf actuator	Beryllium copper	QQ-C-533, 1/4 H
GC-IMP(D)-2058	Bracket	Alum. alloy 6061-T6	Anodize clear, MIL-A-8625, type II.
GE-IMP(D)-1910	Platform support	Alum. alloy 6061-T6	Nut, Kaynar No. MF-7201-04
GE-IMP(D)-1916	Support cover	Alum. alloy 6061-T6	Buffed to $^{8}\mu$ finish

Courtesy of Roland Leland, MSB, GSFC

APPENDIX B

REPORT ON PARTICULATE CONTAMINATION IN HIGH BAY AREA

In an effort to determine the particulate contamination of the high bay area, samples have been taken in which particles were enumerated by the particle count method described in the ARP743. The samples were taken in a 2-day span at different times of day in order to include the variations in activity within the area. The level of particulate contamination is inherent in the following data sheets (Tables B1-10) in view of the following comments.

1. Fibers, which are separately listed are also included in the $>25\mu$ count.
2. Ten grid squares were counted for background. A total of four filters per box of 100 were counted, averaged and multiplied by 10.1 in each size range to give background (F).
3. Areas sampled were Area I-Microbiological Area, Area II-Mechanism Area, Area III-Far Left Corner, and Area IV-Middle Cabinet Area (Figure B-1).

The data compiled by this method indicate that the high bay area is currently maintained in the 100,000 class of the clean room standard.

A second method was employed to determine particulate contamination in the Hi-bay area. This involved the use of a Royco Particle Counter which counted continuously for 9 days (except for a short break on 12/28/66). The particle sizes counted were 0.5μ and larger, and 5.0μ and larger; also, they were counted for 10 minutes each. This exchange of counting the particle sizes continued until the counter completed 9 days of operation.

The results (Figure B-2) indicate that the counts were high during the day when the Hi-bay area was occupied by personnel, and low at night when no one occupied the entire area. The results in Figure B-2 were computed from a printout of figures recorded by the particle counter which records the data 3 times an hour or every 20 minutes.

These tests involving the Royco Particle Counter were conducted by J. E. Bush, Assistant Section Head, Mechanical Systems Branch, Goddard Space Flight Center.

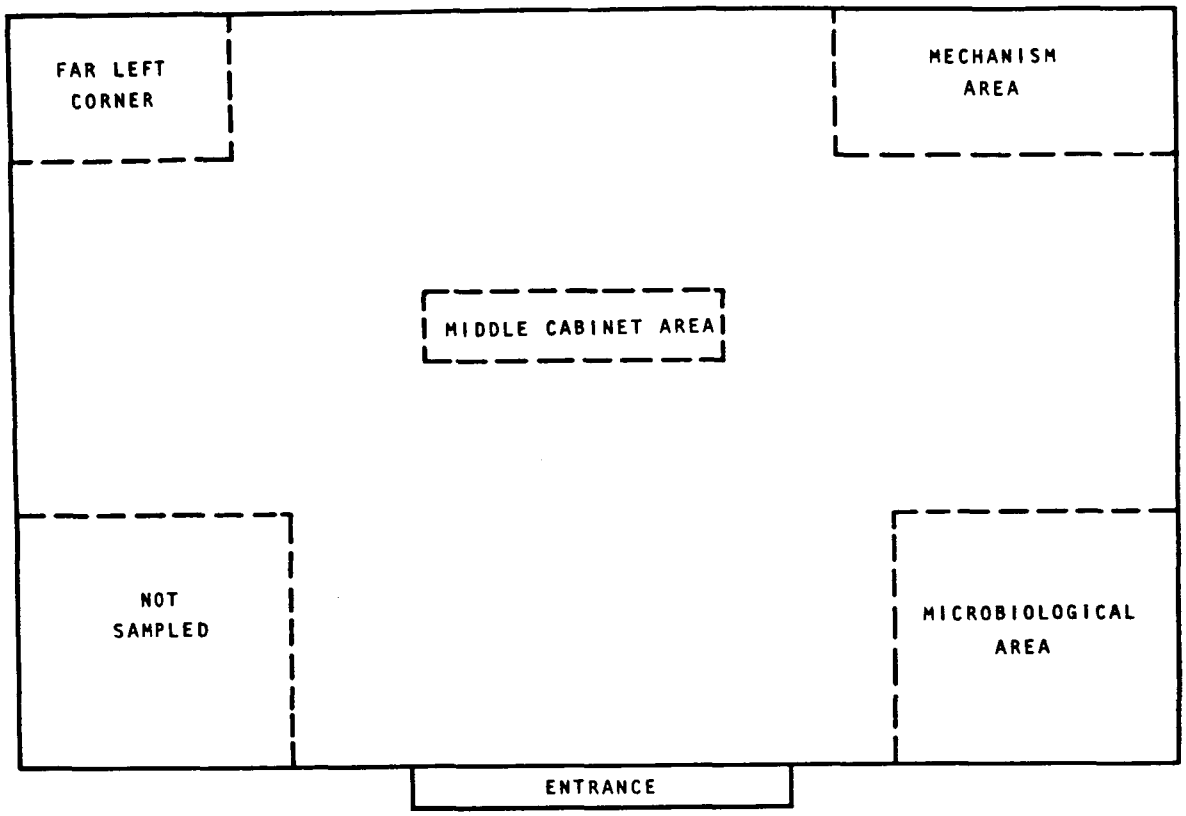

Figure B-1–High-Bay Area Floor Plan, Areas Sampled

Table B-1

PARTICLE COUNT DATA

Room No.	Class	Source	Volume	Filter Type	Time/Day/Month/Year	Collected by	Counted by
Hi-Bay	III	Pump	$10 ft^3$	0.45μ	0905 5 Jan 67	Paige, C.C.	Artest, E.G.

Mag. X	Particle Size μ	Area Per Field MM^2 A	Particles Counted in Each Randomly Selected Field on Filter Paper										Fields Counted B	Particles Counted Total C	X Factor $D = \frac{\text{Total Area}}{A \times B}$	Particles in Sample E = CD	Background F	PPCF $\frac{E-F}{Vol}$
100	5-25	9.49	7	6	4	7	7	1	2	7	4	7	10	52	$\frac{960}{9.49 \times 10} = 10.1$	525	55	47
100	>25	9.49	4	1	3	3	2	3	3	3	3	4	20	79	$\frac{960}{9.49 \times 20} = 5.1$	403	45	36
			1	0	4	1	4	23	2	5	5	2						
100	Fibers	9.49	0	0	1	0	0	0	0	0	0	0	20	2				
			0	0	0	0	0	0	0	0	1	0						

Comments: These data were taken from Area I, Sample #1

Table B-2

PARTICLE COUNT DATA

Room No.	Class	Source	Volume	Filter Type	Time/Day/Month/Year	Collected by	Counted by
Hi-Bay	III	Pump	10ft^3	0.45μ	0950 5 Jan 67	Paige, C.C.	Artest, E.G.

Mag. X	Particle Size μ	Area Per Field MM^2 A	Particles Counted in Each Randomly Selected Field on Filter Paper										Fields Counted B	Particles Counted Total C	X Factor $D = \frac{\text{Total Area}}{A \times B}$	Particles in Sample E = CD	Background F	PPCF $\frac{E-F}{Vol}$
100	5-25	9.49	14	9	7	8	4	4	9	8	11	9	10	83	$\frac{960}{9.49 \times 10}$ = 10.1	838	55	78
100	>25	9.49	3	4	1	2	5	5	2	1	1	6	20	57	$\frac{960}{9.49 \times 20}$ = 5.1	291	45	15
			2	3	1	3	5	1	2	2	5	3						
100	Fibers	9.49	0	0	0	0	0	0	0	0	0	0	20	2				
			0	0	0	0	0	0	0	0	2	0						

Comments: Area I Sample #2

Table B-3

PARTICLE COUNT DATA

Room No.	Class	Source	Volume	Filter Type	Time/Day/Month/Year	Collected by	Counted by
Hi-Bay	III	Pump	$10ft^3$	0.45μ	1455 4 Jan 67	Paige, C.C.	Artest, E.G.

Mag. X	Particle Size μ	Area Per Field MM^2 A	Particles Counted in Each Randomly Selected Field on Filter Paper										Fields Counted B	Particles Counted Total C	X Factor $D = \frac{\text{Total Area}}{A \times B}$	Particles in Sample E = CD	Background F	PPCF $\frac{E-F}{Vol}$
100	5-25	9.49	8	8	11	8	3	14	9	10	7	8	10	86	$\frac{960}{9.49 \times 10}$ 10.1	869	55	81
100	> 25	9.49	2	3	2	3	0	0	5	2	0	4	20	34	$\frac{960}{9.49 \times 20}$ 5.1	173	45	13
			0	2	1	2	3	0	0	2	2	1						
100	Fibers	9.49	0	0	0	0	0	0	0	0	0	0	20	0				
			0	0	0	0	0	0	0	0	0	0						

Comments: Area II Sample #1

Table B-4

PARTICLE COUNT DATA

Room No.	Class	Source	Volume	Filter Type	Time/Day/Month/Year	Collected by	Counted by
Hi-Bay	III	Pump	10ft^3	0.45μ	1555 4 Jan 67	Paige, C.C.	Artest, E.G.

Mag. X	Particle Size μ	Area Per Field MM^2 A	Particles Counted in Each Randomly Selected Field on Filter Paper										Fields Counted B	Particles Counted Total C	X Factor $D = \frac{\text{Total Area}}{A \times B}$	Particles in Sample E = CD	Background F	PPCF $\frac{E-F}{Vol}$
100	5-25	9.49	32	32	29	15	25	31	20	19	25	28	10	256	$\frac{960}{9.49 \times 10} = 10.1$	2586	55	253
100	>25	9.49	6	1	5	8	7	1	3	1	3	3	20	60	$\frac{960}{9.49 \times 20} = 5.1$	306	45	26
			6	2	1	2	4	1	1	1	3	2						
100	Fibers	9.49	0	0	0	0	0	0	0	0	0	0	20	0				
			0	0	0	0	0	0	0	0	0	0						

Comments: Area II Sample #2

Table B-5

PARTICLE COUNT DATA

Room No.	Class	Source	Volume	Filter Type	Time/Day/Month/Year	Collected by	Counted by
Hi-Bay	III	Pump	$10ft^3$	0.45μ	1530 5 Jan 67	Paige, C.C.	Artest, E.G.

Mag. X	Particle Size μ	Area Per Field MM^2 A	Particles Counted in Each Randomly Selected Field on Filter Paper										Fields Counted B	Particles Counted Total C	X Factor $D = \frac{\text{Total Area}}{A \times B}$	Particles in Sample E = CD	Back-ground F	PPCF $\frac{E-F}{Vol}$
100	5-25	9.49	18	10	4	2	2	3	5	5	7	4	10	60	$\frac{960}{9.49 \times 10}$	606	55	55
															10.1			
100	> 25	9.49	7	10	5	1	2	3	1	2	0	1	20	51	$\frac{960}{9.49 \times 20}$	260	45	22
			3	1	3	2	0	0	0	4	3	3			5.1			
100	Fibers	9.49	1	0	0	0	0	0	0	1	0	0	20	2				
			0	0	0	0	0	0	0	0	0	0						

Comments: Area II Sample #3

Table B-6

PARTICLE COUNT DATA

Room No.	Class	Source	Volume	Filter Type	Time/Day/Month/Year	Collected by	Counted by
Hi-Bay	III	Pump	$10ft^3$	0.45μ	1455 4 Jan 67	Paige, C.C.	Artest, E.G.

Mag. X	Particle Size μ	Area Per Field MM^2 A	Particles Counted in Each Randomly Selected Field on Filter Paper										Fields Counted B	Particles Counted Total C	X Factor $D = \frac{\text{Total Area}}{A \times B}$	Particles in Sample E = CD	Background F	PPCF $\frac{E-f}{Vol}$
100	5-25	9.49	10	4	12	8	5	10	8	12	13	10	10	92	$\frac{960}{0.924 \times 10}$ = 103.9	9559	55	950
100	>25	9.49	6	3	1	4	2	4	5	2	4	0	20	55	$\frac{960}{0.924 \times 20}$ = 51.9	2855	45	281
			3	4	3	0	2	4	2	2	1	3						
100	Fibers	9.49	1	0	0	0	0	0	1	0	1	0	20	4				
			0	0	0	0	0	0	0	1	0	0						

Comments: Area III, Sample #1

Table B-7

PARTICLE COUNT DATA

Room No.	Class	Source	Volume	Filter Type	Time/Day/Month/Year	Collected by	Counted by
Hi-Bay	III	Pump	$10 ft^3$	0.45μ	1555 4 Jan 67	Paige, C.C.	Artest, E.G.

Mag. X	Particle Size μ	Area Per Field MM^2 A	Particles Counted in Each Randomly Selected Field on Filter Paper										Fields Counted B	Particles Counted Total C	X Factor $D = \frac{\text{Total Area}}{A \times B}$	Particles in Sample E = CD	Background F	PPCF $\frac{E-F}{Vol}$
100	5-25	9.49	8	2	5	8	6	4	2	9	4	6	10	54	$\frac{960}{9.49 \times 10}$ 10.1	545	55	49
100	>25	9.49	3	2	2	5	0	2	2	2	3	3	20	51	$\frac{960}{9.49 \times 20}$ 5.1	260	45	22
			5	0	3	2	5	1	3	4	1	3						
100	Fibers	9.49	0	0	0	0	0	0	0	0	0	0	20	4				
			1	0	0	1	0	0	0	2	0	0						

Comments: Area III, Sample #2

Table B-8

PARTICLE COUNT DATA

Room No.	Class	Source	Volume	Filter Type	Time/Day/Month/Year	Collected by	Counted by
Hi-Bay	III	Pump	10ft^3	0.45μ	1530 5 Jan 67	Paige, C.C.	Artest, E.G.

Mag. X	Particle Size μ	Area Per Field MM^2 A	Particles Counted in Each Randomly Selected Field on Filter Paper										Fields Counted B	Particles Counted Total C	X Factor $D = \frac{\text{Total Area}}{A \times B}$	Particles in Sample E = CD	Background F	PPCF $\frac{E-F}{Vol}$
100	5-25	9.49	18	5	11	11	10	10	3	5	13	9	10	96	$\frac{960}{9.49 \times 10}$ = 10.1	970	55	92
100	>25	9.49	2	1	4	5	6	2	8	6	5	1	20	71	$\frac{960}{9.49 \times 20}$ = 5.1	362	45	32
			3	1	4	5	3	3	4	3	3	2						
100	Fibers	9.49	0	0	0	1	1	0	2	1	0	0	20	7				
			0	0	0	1	0	0	0	0	1	0						

Comments: Area III, Sample #3

Table B-9

PARTICLE COUNT DATA

Room No. Hi-Bay	Class III	Source Pump	Volume $10ft^3$	Filter Type 0.45μ	Time/Day/Month/Year 0905 5 Jan 67	Collected by Paige, C.C.	Counted by Artest, E.G.

Mag. X	Particle Size μ	Area Per Field MM^2 A	Particles Counted in Each Randomly Selected Field on Filter Paper										Fields Counted B	Particles Counted Total C	X Factor $D = \frac{\text{Total Area}}{A \times B}$	Particles in Sample $E = CD$	Background F	PPCF $\frac{E-F}{Vol}$
100	5-25	9.49	24	18	13	30	17	12	10	12	24	23	10	83	$\frac{960}{9.49 \times 10 \over 10.1}$	838	55	78
100	> 25	9.49	16	3	5	12	3	5	2	4	5	10	10	65	$\frac{960}{9.49 \times 10 \over 10.1}$	657	45	61
100	Fibers	9.49	0	0	0	0	0	0	0	0	0	1	20	1				
			0	0	0	0	0	0	0	0	0	0						

Comments: Area IV Sample #1

Table B-10

PARTICLE COUNT DATA

Room No.	Class	Source	Volume	Filter Type	Time/Day/Month/Year	Collected by	Counted by
Hi-Bay	III	Pump	$10 ft^3$	0.45μ	0950 5 Jan 67	Paige, C.C.	Artest, E.G.

Mag. X	Particle Size μ	Area Per Field MM^2 A	Particles Counted in Each Randomly Selected Field on Filter Paper										Fields Counted B	Particles Counted Total C	X Factor $D = \frac{\text{Total Area}}{A \times B}$	Particles in Sample $E = CD$	Background F	PPCF $\frac{E-F}{Vol}$
100	5-25	9.49	16	25	19	18	17	13	20	18	24	23	10	93	$\frac{9960}{9.49 \times 10}$ 10.1	939	55	88
100	>25	9.49	8	4	2	4	1	1	4	9	6	6	20	81	$\frac{960}{9.49 \times 20}$ 5.1	413	45	37
			3	4	4	3	5	3	5	1	2	6						
100	Fibers	9.49	0	0	0	0	0	0	0	0	0	0	20	0				
			0	0	0	0	0	0	0	0	0	1						

Comments: Area IV, Sample #2

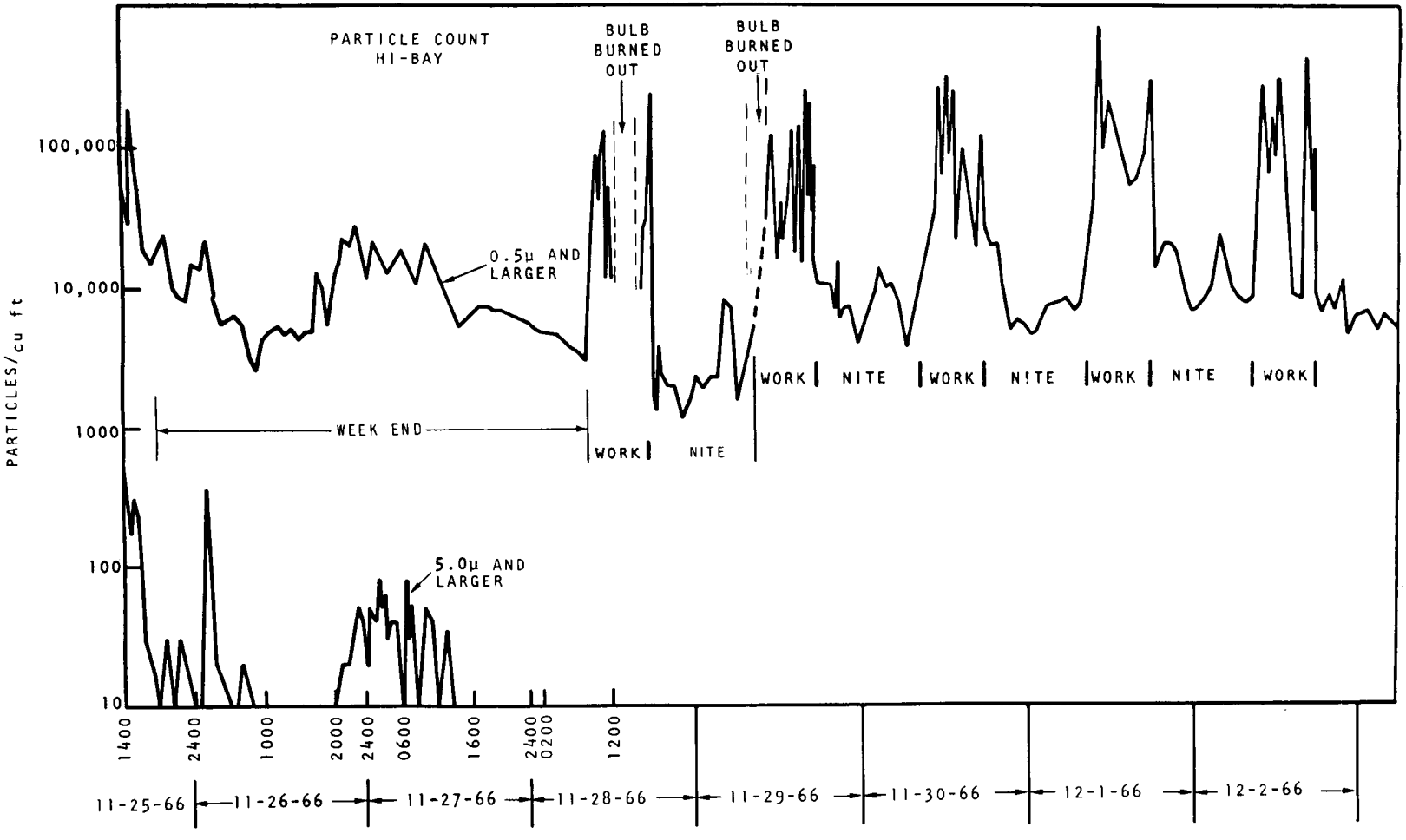

Figure B-2–Particle Count from High-Bay Area

APPENDIX C

DEFINITIONS OF SURFACE AREA CLASSIFICATIONS

The various areas of the AIMP-D spacecraft were classified with respect to the manner in which they were occluded by other parts of the spacecraft or exposed to their environment.

Area Classifications

A — Interior surface areas of the module frames which included walls, cavities, and electronic circuit boards but electronic components were omitted.

B — Occluded surfaces were obstructed by module frames excluding exposed surfaces of the stack of module frames.

C — Cover and occluded inner surfaces of the spacecraft

D — Other interior surfaces and volumes of the spacecraft

1. Body
2. Motor, volume of propellant
3. Assembly of occluded surfaces

E — Exterior surfaces of spacecraft

1. Body
2. Motor
3. Assembly of occluded surfaces

The record sheets (Figure C-1) are samples of the sheets that were used to record data of bio-samples taken from the AIMP-D. The record sheets shown in Figure C-2 are samples of the sheets that will be used to record the data of bio-samples taken from AIMP-E.

The mathematical computations of all surface areas were determined by Roy Courtney, Spacecraft Structures and Integration Section, Mechanical Systems Branch, Goddard Space Flight Center.

MECHANICAL SYSTEMS BRANCH
STRUCTURAL AND MECHANICAL APPLICATION SECTION
VIABLE MICROBIAL COUNT
AIMP D & E SPACECRAFT

SPACECRAFT_____ UNIT _____

OCCLUDED "A"	AREA IN SQUARE INCHES		VIABLE COUNT AT TIME OF		TOTALS		
INTERIOR OF ELECTRONIC CIRCUIT MODULES	TOTAL	SAMPLED	CONFORMAL COATING	ENCAPSULATION	SUB	$\frac{A \times E}{B}$ =	ACCUMULATIVE
	A	B	C	D	E	VIABLE	COUNT
F-1 Command Decoder No. 2	153						
F-2 Range and Range Rate No. 2	153						
F-3 Range and Range Rate No. 1	147						
F-3a Range and Range Rate No. 1 Plates	164						
F-4 Range and Range Rate No. 3	105						
F-4a Range and Range Rate No. 3 Plates	164						
F-5 Transmitter	180						
F-5a Transmitter Plates	123						
G-1 University of California Ion Chamber	141						
G-2 Command Receiver No. 2	148						
G-3 Ames Data Handling	133						
G-4 Ames Signal Processor	143						
G-5 Ames Sensor Electronics	143						
H-1 U.I. Particle Detectors	171						
H-2 Programmer No. 2 (IV Stage Timers)	135						

Figure C-1–Record Sheets for Recording Data of Bio-Samples Taken from AIMP-D

MECHANICAL SYSTEMS BRANCH
STRUCTURAL AND MECHANICAL APPLICATIONS SECTION
VIABLE MICROBIAL COUNT
AIMP D & E SPACECRAFT

SPACECRAFT_____ UNIT_____

EXTERIOR SURFACES "E"	AREA IN SQUARE INCHES		VIABLE COUNT	TOTALS	
EXTERIOR SURFACES OF SPACECRAFT	TOTAL	SAMPLED		$\frac{A \times C}{B} =$	ACCUMU-LATIVE
	A	B	C	VIABLE	COUNT
1 – BODY					
38. GSFC Flipper	100				
39. Ames Flipper	100				
40. Boom Tension Adjuster	10				
41. Antenna Rod	25				
42. Antenna Cup	4				
43. Antenna Nubbin	8				
44.					
45.					
46.					
47.					
48.					
49.					
2 – MOTOR					
50. Retromotor Case	490				
51. Motor Igniter	8				
52. Motor Nozzle	227				
53. Motor Collar	6				
54. Motor Mounting Ring	33				
55. Motor Bolts	8				
56. Cable	29				

Figure C-1 (Continued)–Record Sheets for Recording Data of Bio-Samples Taken from AIMP-D

MECHANICAL SYSTEMS BRANCH
STRUCTURAL AND MECHANICAL APPLICATIONS SECTION

DECONTAMINATION RECORD

UNIT NAME _____ SERIAL NO. _____

LINE ITEM _____ SPACECRAFT UNIT _____

AT TIME OF CONFORMAL COATING

Condition	Exposure		Bacteria Count						Performed By	Date
			Sample No.							
	Method	Time	1	2	3	4	5	6		
Contaminated										
Decontaminated										

AT TIME OF ENCAPSULATION

Contaminated										
Decontaminated										

IN THE FIELD

Contaminated										
Decontaminated										

SPORE STRIP — Positive Growth ☐ — Negative Growth ☐

670-27 (8/64)

CERTIFICATION

Name _____

Title _____

Date _____

Figure C-1 (Continued)—Record Sheets for Recording Data of Bio-Samples Taken from AIMP-D

MECHANICAL SYSTEMS BRANCH UNIT_____

STRUCTURAL AND MECHANICAL APPLICATION SECTION

VIABLE MICROBIAL COUNT

AIMP E SPACECRAFT

AREA CLASS		TOTAL AREA (IN^2)	COMPILATION OF COUNTS OF VIABLE ORGANISMS (Microorganisms/2 x Total Area)							
			CONTAMINATED				DECONTAMINATED			
			Aerobic		Anaerobic		Aerobic		Anaerobic	
			Veg.	Spores	Veg.	Spores	Veg.	Spores	Veg.	Spores
Occluded "A": Interior of Module Frames										
Item	Module Frame Flown									
A-1	EG2–	151								
A-2	EG3–	151								
A-3	ET2–	209								
B-1	IA3–	151								
B-2	IA2–	257								
B-2a	IA1–	58								
B-3	IP5–	63								
B-3	IP4–	312								
B-3a	–	164								
C-1	EM3–	141								
C-2	EM2–	141								
C-3	IG1–	136								
C-4	ID2–	141								
C-5	IP2–	66								
C-6	IG3–	66								
C-7	IS21–	83								
D-1	EM1–	335								
E-1	IT8–	162								
E-2	IP6–	133								
E-3	ID1–	225								
E-3a	–	164								
F-1	IT5–	153								
F-2	IT3–	153								
F-3	IT2–	147								
F-3a	–	164								
F-4	IT4–	105								
F-4a	–	164								
F-5	IT1–	180								
F-5a	–	123								
G-1	EC1–	141								
G-2	IG4–	136								
G-3	IT6–	148								
G-4	EA2–	133								
G-5	EA3–	143								
G-6	EA4–	143								
H-1	ES2–	300								
H-2	EI1–	171								
H-3	IG2–	135								
	TOTAL AREA									
	2X TOTAL AREA									
	FINAL TOTAL									

Figure C-2–Revised Record Sheets for Recording Data of Bio-Samples Taken from AIMP-E

MECHANICAL SYSTEMS BRANCH UNIT _____
STRUCTURAL AND MECHANICAL APPLICATION SECTION
VIABLE MICROBIAL COUNT
AIMP E SPACECRAFT

Sheet 2 of 2

AREA CLASS	PAGE	TOTAL AREA (IN^2)	COMPILATION OF COUNTS OF VIABLE ORGANISMS (Microorganisms/Total Area)							
			CONTAMINATED				DECONTAMINATED			
			Aerobic		Anaerobic		Aerobic		Anaerobic	
			Veg.	Spores	Veg.	Spores	Veg.	Spores	Veg.	Spores
Occluded "B": Surfaces that Module Frames Occlude	B-1									
Occluded "C": Exterior of Module Frames	C-2									
Occluded "C": Other Interior Exposed Surfaces of the Spacecraft that the Cover Occludes	C-3									
Interior Surfaces "D": Other Interior Surfaces of the Spacecraft										
–1 Body	D-2									
–2 Motor	D-2									
–3 Assembly Occluded	D-4									
Exterior Surfaces "E": Exterior Surfaces of the Spacecraft										
–1 Body	E-3									
–2 Motor	E-4									
–3 Assembly Occluded	E-6									
Interior Burden of Components "F"	F-1	–								
Final Totals of Contamination of the AIMP-E Spacecraft										

Figure C-2 (Continued)–Revised Record Sheets for Recording Data of Bio-Samples Taken from AIMP-E

MECHANICAL SYSTEMS BRANCH
STRUCTURAL AND MECHANICAL APPLICATIONS SECTION
VIABLE MICROBIAL COUNT
AIMP E SPACECRAFT

UNIT _____

Sheet B-1

ITEM	OCCLUDED "B": SURFACES THAT MODULE FRAMES OCCLUDE	TOTAL AREA (IN^2)	COUNT OF VIABLE ORGANISMS (Microorganisms/Total Area)									
			① CONTAMINATED					② DECONTAMINATED				
			Date	Aerobic		Anaerobic		Date	Aerobic		Anaerobic	
			Area Sampled	a Veg.	b Spores	c Veg.	d Spores	Area Sampled	a Veg.	b Spores	c Veg.	d Spores
1	C-Frame & Connectors (8 Facets)	460										
2	Struts from Platform to C-Frames(8)	78										
3	Inside Surface Front Cover Plates (8)	100										
4	Frame Bolts to Stack Height (32 bolts)	106										
5	Platform Top Covered by Frame (8 Facets)	384										
6	O.A. Sensor Connector Standoff	10										
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												
21												
22												
	TOTALS											

Figure C-2 (Continued)–Revised Record Sheets for Recording Data of Bio-Samples Taken from AIMP-E

MECHANICAL SYSTEMS BRANCH
STRUCTURAL AND MECHANICAL APPLICATION SECTION
VIABLE MICROBIAL COUNT
AIMP E SPACECRAFT

UNIT_____

Sheet C-1 of 2

ITEM	OCCLUDED "C": EXTERIOR OF MODULE FRAMES	TOTAL AREA (IN^2)	UNIT SAMPLED	COUNT OF VIABLE ORGANISMS (Microorganisms/Total Area)									
				① CONTAMINATED					② DECONTAMINATED				
				Date	Aerobic		Anaerobic		Date	Aerobic		Anaerobic	
				Area Sampled	a Veg.	b Spores	c Veg.	d Spores	Area Sampled	a Veg.	b Spores	c Veg.	d Spores
A-1	GSFC Fluxgate A/D Electronics	151	EG2–										
A-2	GSFC Fluxgate Electronics	151	EG3–										
A-3	Temple University Cosmic Dust Experiment	209	ET2–										
B-1	Optical Aspect Computer	151	IA3–										
B-2	Optical Aspect Amplifier	151	IA2–										
B-2a	Optical Aspect Sensor	58	IA1–										
B-3	Optical Aspect Converter	63	IP5–										
B-3	Prime Converter	191	IP4–										
B-3a	Prime Converter Plates	164	–										
C-1	MIT Plasma Probe Logic Card No. 3.	141	EM3–										
C-2	MIT Plasma Probe Logic Card No. 2	141	EM2–										
C-3	Programmer No. 1 (Undervoltage)	136	IG1–										
C-4	Performance Parameters	141	ID2–										
C-5	Solar Array Regulars	66	IP2–										
C-6	Programmer No. 3 (Flipper Control)	66	IG3–										
C-7	Turn on Plug and Ordnance Plug	83	IS21										
D-1	MIT Plasma Probe	335	EM1–										
E-1	Antenna Hybrid	162	IT8–										
E-2	Encoder Converter	225	IP6–										
E-3	Telemetry Encoder	225	ID1–										
E-3a	Telemetry Encoder Plates	164	–										
F-1	Command Decoder No. 2	153	IT5–										
F-2	Range and Range Rate No. 2	153	IT3–										

Figure C-2 (Continued)–Revised Record Sheets for Recording Data of Bio-Samples Taken from AIMP-E

MECHANICAL SYSTEMS BRANCH
STRUCTURAL AND MECHANICAL APPLICATION SECTION
VIABLE MICROBIAL COUNT
AIMP E SPACECRAFT

UNIT ____

Sheet A-1 of 4

ITEM	OCCLUDED "A": INTERIOR OF MODULE FRAMES	TOTAL AREA (IN^2)	COUNT OF VIABLE ORGANISMS (Microorganisms Total Area) ① CONTAMINATED Date / Area Sampled / Aerobic a Veg. / Aerobic b Spores / Anaerobic c Veg. / Anaerobic d Spores	② DECONTAMINATED PRE-CONFORMAL COATING Date / Area Sampled / Aerobic a Veg. / Aerobic b Spores / Anaerobic c Veg. / Anaerobic d Spores	③ CONTAMINATED Date / Area Sampled / Aerobic a Veg. / Aerobic b Spores / Anaerobic c Veg. / Anaerobic d Spores	④ DECONTAMINATED PRE-ENCAPSULATION Date / Area Sampled / Aerobic a Veg. / Aerobic b Spores / Anaerobic c Veg. / Anaerobic d Spores	Microorganisms 2x Total Area SUM OF 2 & 4 a_2+a_4 b_2+b_4 c_2+c_4 d_2+d_4
A-1	GSFC Fluxgate A/D Electronics EG2–	151					
	EG2–						
	EG2–						
A-2	GSFC Fluxgate A/D Electronics EG3–	151					
	EG3–						
	EG3–						
A-3	Temple University Cosmic Dust Experiment ET2–	209					
	ET2–						
B-1	Optical Aspect Computer IA3–	151					
	IA3–						
	IA3–						
B-2	Optical Aspect Amplifier IA2–	257					
	IA2–						
B-2a	Optical Aspect Sensor IA1–	58					
	IA1–						
	IA1–						
B-3	Optical Aspect Converter IP5–	63					
	IP5–						
B-3	Prime Converter IP4–	312					
	IP4–						
B-3a	Prime Converter Plates –	164					
	–						

Figure C-2 (Continued)–Revised Record Sheets for Recording Data of Bio-Samples Taken from AIMP-E