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A Study Program on the Development of a Mathematical Model(s) for Microbial Burden Prediction

Final Report Addendum

Volume IV Technical Report

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MARTIN MARIETTA CORPORATION

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A STUDY PROGRAM ON THE DEVELOPMENT OF MATHEMATICAL MODEL(S) FOR MICROBIAL BURDEN PREDICTION

JPL Contract 952028

Final Report

Addendum

Volume IV, Technical Report

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FOREWORD

This document represents an addendum to the final technical report on JPL Contract 952028, A Study Program on the Development of a Mathematical Model(s) for Microbial Burden Prediction. This addendum covers the work performed in Phases IV, V and VI of the subject contract and is submitted in two volumes:

Volume IV - Addendum - Technical Report

Volume V - Appendices

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ILLUSTRATIONS

<u>DEFINITIONS AND ABBREVIATIONS</u>

1) <u>Exterior Exposed Surfaces</u> - Those surfaces of an assembly, subsystem, or system that would be illuminated if placed at the center of an inwardly directed luminous sphere.

2) <u>Exterior Exposed Surface Burden</u> - The viable organisms existing on the exterior exposed surface of an item.

3) <u>Mated Surface Burden</u> - The viable organisms trapped between mating surfaces such as under screws and in joints.

4) <u>Occluded Surfaces</u> - Those surfaces of an assembly, subsystem, or system that are not exterior exposed surfaces but which would get wet if the item were immersed in a fluid.

5) <u>Zone</u> - A portion of the spacecraft that may be uniquely identified by consideration of such things as functional attributes of a subsystem, geometry, and thermal behavior.

6) <u>Biologically Significant Zone</u> - A zone for which the burden accumulation process differs considerably from that of other zones due to differences in orientation, surface material, contact, etc.

7) <u>Assembly Initial Burden</u> - The burden present on an assembly at the time the assembly is integrated to its zone.

8) <u>Interval Concept</u> - A numerical technique for performing arithmetic operations of addition, subtraction, multiplication, and division on histograms (probability density functions). The histograms include, but are not limited to, representation of the probability of occurrence versus the number of microorganisms.

9) <u>Level of Activity</u> - One of four levels of detail in the representation of an assembly and test sequence in the burden prediction model; these levels, in order of increasing detail, are:

First level (STAGE)
Second level (TASK)
Third level (SUBTASK)
Fourth level (OPERATION)

10) Functional Analysis - Determination of the detailed steps (functions) required to perform a given activity.

11) Spores - Microorganisms in a dormant, resistant state. Sample counts for spores are generally obtained by heating the sample (heat shock) to destroy vegetative organisms.

12) Vegetative Organisms - Microrganisms actively engaged in growth and reproduction. Due to the culture techniques normally used, the sample counts for vegetative organisms may include spores as well.

ABBREVIATIONS

AFETR	Air Force Eastern Test Range,
DFR	Dual Frequency Receiver,
EA	Electronics Assembly,
MV67	The Mariner Venus 1967 - 2 Spacecraft,
OSE	Operational Support Equipment,
PAS	Pyrotechnics Arming Switch,
PIPS	Postinjection Propulsion Subsystem,
SIT	Separation-Initiated Timer,
TRD	Trapped Radiation Detector.
S/A	Subassembly
JPL	Jet Propulsion Laboratory
ESF	Explosive-Safe Facility

I INTRODUCTION

This addendum to the final report describes work performed by Martin Marietta during Phases IV, V, and VI of JPL Contract 952028 -- A Study Program on the Development of a Mathematical Model(s) for Microbial Burden Prediction. This work was performed between 1 June and 15 October under Modification No. 1 to the contract.

During Phases I, II, and III of the contract, a microbial burden prediction model was developed and tested.

In Phase I, a representative assembly and test sequence was selected as a test case and was detailed to a level that permitted a one-to-one correspondence between operations being performed and the microbial burden accumulation parameters.

In Phase II, two processes that affect burden accumulation on hardware were identified:

1) Fallout from airborne organisms;
2) Contact by contaminated hands or tools.

Mathematical expressions were developed to represent these processes, and the resulting parameters were related to attributes of the assembly and test activities. Also included in Phase II was the development of a computer program to permit simulation of the assembly and test sequence and to perform the burden prediction calculations for each operation in the sequence.

In Phase III the selected test case was prepared for simulation, and the microbial burden prediction model was used to calculate the resulting burden accumulation. No particular effort was made to ensure that the parameters used were accurate since the test case was prepared only to enable verification of the model's operation.

Phases I, II, and III are discussed in detail in Volume I of the final report.

In Phase IV, an attempt was made to obtain accurate values for parameters used in the microbial burden prediction model. These parameters were needed for the burden predictions to be performed for the Mariner Venus 67 Number 2 Spacecraft (MV 67) (Phases V and VI) and, depending on the accuracy of the predictions, could be refined for use in future applications of the burden prediction model.

As is common in biological work, precise values could not be obtained for the parameters due to the variability of the experimental results. The microbial burden prediction model was designed to circumvent this difficulty by permitting uncertain parameters to be input as histograms. The histograms, representing probability distributions for the parameter values, are determined directly from the distribution of the data values so that the uncertainty of the parameters is included in the burden calculations. Much of the data used in preparing histograms was obtained from records of the extensive biological sampling performed during the assembly and test of the MV 67. Assays of swab samples and stainless steel "carrier strips" and "environmental coupons" were made at approximately weekly intervals. (The MV 67 biological sampling program is discussed in Reference 1.) Most of the model input data was based on environmental coupon assays.

Where necessary, additional data were obtained from experiments described in the literature and from records of work performed by Martin Marietta.

In Phase V, a simulation of the planned assembly and test sequence was prepared as specified in <u>Mariner Venus 1967 Spacecraft Assembly</u> (Ref 4), <u>Mariner Venus 1967 Test and Operations Plan</u> (Ref 5), and <u>Mariner Venus 1967</u>

System Test and Operations Report (Ref 6). Activities were organized into stages, tasks, subtasks, and operations as required for model inputs. (The greatest detail is represented by the operation level; at this level, the parameter values can be directly related to the activities being performed.) Each subtask was composed of a combination of 17 generic operations identified in the assembly and test sequence (Table 6).

A list was maintained of all parts (except screws and similar small items) mentioned in the assembly and test sequence. Dimensions were obtained for these parts, and their surface areas were calculated. During the assembly simulation, These parts were incorporated into a number of zones, for which separate burden predictions were maintained. These zones generally correspond to hardware units, but were chosen to represent areas of nearly uniform burden accumulation.

The Phase V burden prediction was retained for comparison with the prediction calculated in Phase VI.

In Phase VI, the burden prediction was based on the actual assembly and test sequence of the MV 67 as recorded in References 2 and 3. The same parts and zones were used as in Phase V, but the stages, tasks, and subtasks were considerably different since many of the activities were not performed in the order planned. The list of operations was the same for Phases V and VI, but they were arranged into different subtasks for the two simulations.

In both Phase V and Phase VI, separate predictions were made for vegetative organisms and for spores. Mean values of the burden predictions are shown in Table 1. (The complete output histograms are given in Tables 11 and 12 in Chapter III.)

Table 1 Final Burden Predictions

	Phase V		Phase VI	
	Spores	Vegetative	Spores	Vegetative
Exterior Surfaces	57.8	7750	69.7	4058
Mated Surfaces	18.6	1020	9.1	437
Total	83.1	8775	79.7	4521

Burdens in thousands of organisms

Although the predicted burdens for Phase V differ from those for Phase VI the differences are not great compared to the ranges of the burden histograms. For the purposes of this contract, a significant burden difference was defined as one log; i.e., a factor of 10. Since the burden predictions for Phases V and VI differed at most by a factor of about 2, the differences are not considered significant.

During the Phase V and Phase VI simulations the burden concentration (organisms/sq ft) seldom varied by a factor of more than 2 from their long term averages. (The burdens, of course, changed as area was added to or removed from the spacecraft.) The stability of the burden is attributed to the care with which personnel and environmental contamination sources were controlled during assembly and test of the MV 67.

II TECHNICAL DISCUSSION

A. PHASE IV

The preparation of input data histograms for the microbial bruden prediction program was based as much as possible, on the microbiological assay records for the MV 67. Supplementary data relating to contact and fallout were obtained from References 7, 8, and 9 as described later in this chapter. In addition, some unpublished data on research performed at the Martin Marietta Denver Facility were used. The procedure used to derive histograms to represent the data was:

1) The data sample points (generally plate counts of assays) were grouped into appropriate intervals. These intervals were chosen to increase logarithmically in length and to divide the data into ten groups;

2) The probability of occurrence of a value in each interval was estimated by the ratio of sample points in this group divided by the total number of sample points. No smoothing was applied.

After preliminary histograms had been prepared, pairs of related histograms were tested to determine whether they represented the same values. For example, the carrier strip assays for different bays of the octagon were tested to see if their values were significantly different. The Kolmogorov-Smirnov test* indicated no significant differences between bays at the 5% level of significance, so it was assumed that carrier strip data for all bays could be combined to give a larger sample size. The Kolmogorov-Smirnov test was used for all such comparisons in Phase IV.

*The Komogorov-Smirnov test is discussed in Ref 10, p 426, and in Ref 11, p 127. Tables of critical values for this test are on p 278 of Ref 11 and pp 427, 428 of Ref 10.

All histograms are presented in this report in the same format as used to input the burden prediction program:

	P_1	P_2	P_3	...	P_n
X_1	X_2	X_3	X_4	...	X_{n+1}

P_n is the probability that the parameter value lies in the interval X_n to X_{n+1}.

Most of the data was grouped into histograms having 10 intervals. However, since the computer time for running the microbial burden prediction program is proportional to the square of the number of intervals, abbreviated versions of many histograms were provided with only five intervals. These abbreviated histograms permitted preliminary simulations to be performed more quickly and with similar results. The abbreviation was accomplished by combining adjacent intervals and adding their probabilities.

Burden prediction formulas used in the Phase V and Phase VI simulations were as follows:

Fallout: $B' = Be^{-t/v} + AvR(1 - e^{-t/v})$

$R = f_2 g(c + \lambda Q)$

Contact: $B' = B(1 - \frac{aS_2}{2A}) + \frac{aS_1}{2} b_t$

where B' is the resulting burden (organisms)*,

B is the initial burden (organisms)*,

e = 2.71828 ...,

t is the activity time (hours)*,

v is the "average lifetime" (hours)*,

A is the surface area (sq ft),

R is the fallout rate $(\frac{\text{organisms}}{\text{sq ft-hr}})$*,

f_2 is the fallout velocity (ft/hr),

g is the surface retention factor for fallout (dimensionless),

c is the environmental airborne contamination (organisms/cu ft)*,

λ is the personnel airborne contamination (organisms/cu ft per man),

Q is the number of men working within 5 ft of the surface*,

a is the area contacted (sq ft),

S_2 is the hand or tool retention factor for contact (dimensionless)*,

S_1 is the hardware retention factor for contact (dimensionless)*,

b_t is the contamination on hand or tool (organisms/sq ft)*.

*These parameters are generally represented as histograms.

The formula for R differs from the one developed during Phase II, namely:

$$R = f_i g(c + Qe^{-\lambda d})$$

where R, F_i, g, and c are unchanged,

Q is the personnel airborne concentration (organisms/cu ft),

λ is a distance reduction factor (1/ft),

d is the distance from the worker to the surface (ft).

The reason for this change is described in Chapter VI of this volume and amounts to the introduction of a linear relation between the number of men in an area and the number of airborne organisms per cu ft..

The MV 67 experienced seven different environments during its assembly and test:

1) Vertical Laminar Flow Tent;
2) High Bay;
3) Space Simulator;
4) Vibration Test Facility;
5) Canister (Sealed for shipment);
6) Hangar AO, AFETR;
7) ESF, AFETR

(The environment "under shroud with N_2 purge" was assumed the same as #1 above.)

For each environment values were determined for:

1) Average Lifetime, v;
2) Environmental organisms/cu ft, c;
3) Additional organisms/cu ft per man, λ;
4) Distributions for c and v;
5) Fallout Velocity, f_2.

Average Lifetime, v

Two different methods were used to obtain values for v.

From Reference 7, v was estimated by determining graphically the time for the burden to reach 63% of its plateau value*. This method gave 8 sample points:

From Ref 7, Fig 1 (horizontal) : 228, 446, 382, 192 hours.

From Ref 7, Fig 2 (vertical) : 15, 307, 15, 252 hours.

These data were obtained for stainless steel strips exposed in a laboratory at Ft. Detrick, Maryland. The Kolmogorov-Smirnov test showed that the two samples did not differ significantly.

From Reference 8, v was estimated from the relation $v = \frac{\text{Plateau Burden}}{\text{Fallout Rate}}$. Data were obtained for v from samples taken at the Martin Company in Baltimore, Maryland. Three areas were sampled: two clean rooms and the adjacent factory. When tested, the factory and one clean room (cleaning area) showed no difference, but both of these rooms differed significantly from the other clean room (assembly area). However, since this difference was caused by only 8 low values (under 10 hours) for v in the assembly clean room, it was decided to include this data anyway. No significant difference was found between aerobes and anaerobes, so it was assumed that these data could be combined. This gave a total of 69 sample points for v. (Note that since fallout rate R is difficult to determine for spores, these data are for vegetative organisms and spores combined.)

*In the burden prediction formulas, when $t = v$, and $B = 0$, $B' = AvR(1-e^{-1}) = .632\ AvR$. AvR is the plateau burden.

Factory Aerobes: 49.06, 16.67, 15.625, 9.54, 33.99, 26.8, 19.6, 44.7, 28.6, 20.7, 22.9, 73.4, 21.3, 36.1, 90.9 hours.

Factory Anaerobes: 3.33, .99, 1.17, 2.00, 6.66, 15.7, 8.33, 14.0, 12.63, 9.09, 4.76, 125., 6.66, 2., 60 hours.

Cleaning Area, Aerobes: 26.56, 32.2, 112.5, 22.66, 9.7, 126., 57.89, 15., 21.2, 13.1, 30., 15., 33.7, 11.3, 45 hours.

Cleaning Area, Anaerobes: 10., 300 hours.

Assembly Area, Aerobes: 1.08, 40.9, 10., 14., 9.5, 8., 9.44, 63., 35.3, 3.38, 48.3, 8.7, 10., 5.3, 7.37 hours.

Assembly Area, Anaerobes: 1.18, 20., 20., 10., 6.67, 60., 20 hours.

(Samples where fallout rate was zero were omitted.)

The histogram for the combined values was:

Average Lifetime, v

	.013	.039	.026	.039	.169	.221	.143	.156	.104	.090
.0001	1.	2.	3.	5.	10.	20.	30.	60.	140.	450.

Abbreviated version of the Average Lifetime Histogram

	.052	.065	.390	.299	.194
.0001	2.	5.	20.	60.	450.

Since no significant difference could be affirmed between the factory and clean room, it was assumed that the above distribution was satisfactory for all environments. For mated surfaces, the value of v was arbitrarily increased by a factor of ten. The above histograms were also used for spores since no suitable data were available for spores alone.

Airborne Contamination, c and λ

Values for c and λ for Hangar AO (AFETR) were obtained directly from Fig 11 in Ref 9. For the other environments, these parameters were estimated from MV67 data by correlating the carrier strip data with the number of men working and the environment. The burden prediction formulas were used to calculate the burden each time the number of men changed, and this burden was compared with the carrier strip burden. The values of c and λ (for each environment) were adjusted until good correlation was obtained. For the period 12 January to 23 February (during which time the spacecraft experienced only tent and high bay environments) the values were as follows:

Date	1/19	1/26	2/2	2/8	2/15	2/23
Predicted	332	896	798	1386	1470	3873
Assay	485	4010*	1655	2845	970	2905

*Several excessively large plate counts were observed.

Since the difference (except for the bad assay) was less than 1/2 log, this was considered satisfactory. Similar methods applied to the other environments gave the following values:

Environment	Vegetative Aerobes		Aerobic Spores	
	c	τ	c	τ
1. Tent	.05	.6	.003	.036
2. Hi Bay	.1	.933	.008	.078
3. Simulator	.5	1.61	.079	.253
4. Vibr. Fac.	.3	.435	.011	.016
5. Canister	1.0	0.	.06	0.
6. Hangar AO	.23	.401	.02	.033
7. ESF	.05	.6	.003	.036

These are, of course, the nominal values; the corresponding distributions from environmental coupon assays were used except for environments #5, #6, and #7 which shared the distributions for #1, #2, and #1, respectively. For vegetative organisms, the histograms were as given in Table 2.

The values of c and λ for spores were obtained by multiplying the values for vegetative organisms by the ratio of spores to vegetative organisms:

Environ #	1	2	3	4	5	6	7
Ratio	.0595	.0831	.1574	.0374	.0595	.0831	.0595

The distributions used for c and λ for spores were the corresponding spore environmental histograms given in Table 3.

Fallout Velocity, f

Since the MV 67 spacecraft was repositioned frequently, it was assumed unimportant to distinguish between surface 1 (exterior, upward facing) and surface 2 (exterior, other). Surface 2 was used to represent all exterior surfaces, hence, of the two fallout velocity parameters f_1 and f_2, only f_2 was used. Its value was determined from data in Reference 8 by correlating fallout rate, R, with the airborne concentration of organisms: $f = R/c$

where: f = fallout velocity (ft/hr)

R = fallout rate $\left(\frac{\text{organisms}}{\text{sq ft-hr}}\right)$

c = airborne concentration $\left(\frac{\text{organisms}}{\text{cu ft}}\right)$.

Table 2 Environmental Histograms, Vegetative Aerobes

#1 Laminar Downflow Tent (135 sample points) Also used for environments #5 (Canister) and #7 (ESF).

	.3333	.2074	.1333	.1482	.0741	.0222	.0074	.0074	.0593	.0074
0	480	960	1440	2400	4800	9600	14400	28800	67200	500,000

	.5407	.2815	.0963	.0148	.0667
0	960	2400	9600	28800	500,000

#2 High Bay (127 sample points) Also used for environment #6 (Hangar AO).

	.0551	.0945	.0709	.1339	.2992	.1496	.0472	.0787	.0709
0	480	960	1440	2400	4800	9600	14400	28800	67200

	.1496	.2048	.4488	.1259	.0709
0	960	2400	9600	28800	67200

#3 Space Simulator (120 Sample Points)

	.0417	.0417	.0250	.0750	.3250	.3167	.0500	.0500	.0750
0	480	960	1440	2400	4800	9600	14400	28800	67200

	.0834	.1000	.6417	.1000	.0750
0	960	2400	9600	28800	67200

#4 Vibration Facility (107 sample points)

	.0841	.1402	.1495	.1776	.2617	.0654	.0187	.0561	.0280	.0187
0	480	960	1440	2400	4800	9600	14400	28800	67200	500,000

	.2243	.3271	.3271	.0748	.0467
0	960	2400	9600	28800	500000

Note: Data for the above histograms was obtained from (horizontal) environmental coupon assays for the period 27 January to 20 April 1967. The coupons were exposed in the areas named.

Table 3 Environmental Histograms, Aerobic Spores

#1 Laminar Downflow Tent (130 sample points)
Also used for environments #5 (Canister) and #7 (ESF).

	.6154	.2615	.0923	.0077	.0231
0	480	960	1440	1920	2400

#2 High Bay (130 sample points)
(Also used for environment #6 (Hangar AO)

	.3846	.2846	.1385	.0769	.0692	.0077	.0231	.0154
0	480	960	1440	1920	2400	3360	4800	7200

	.3846	.2846	.2154	.0769	.0385
0	480	960	1920	3360	7200

#3 Space Simulator (120 sample points)

	.1917	.2000	.1250	.1667	.1167	.1083	.0583	.0333
0	480	960	1440	1920	2400	3360	4800	7200

	.1917	.2000	.2917	.2250	.0916
0	480	960	1920	3360	7200

#4 Vibration Facility (120 sample points)

	.7167	.1917	.0750	.0083	0	0	0	.0083
0	480	960	1440	1920	2400	3360	4800	7200

	.7167	.1917	.0833	0	.0083
0	480	960	1920	3360	7200

Note: Data for the above histograms was obtained from (horizontal) environmental coupon assays for the period 27 January to 20 April, 1967. The coupons were exposed in the areas named.

Data for vegetative aerobes in the three environments sampled (factory and two clean rooms) were as follows:

$c' = c + Q\lambda$	R
2.8	161.
3.2	312.
4.6	256.
7.2	367.
2.8	153.
3.2	242.
3.7	300.
3.2	190.
2.2	192.
2.3	347.
3.6	231.
1.2	79.
3.7	164.
2.8	194.
1.2	77.
2.2	159.
0.8	64.
0.4	18.
0.7	4.
0.2	15.
0.4	37.
0.08	5.
0.7	19.
0.7	18.
0.4	16.
0.2	29.
0.2	15.
0.2	16.
0.2	8.
0.4	38.
0.2	10.
0.5	50.
0.8	46.
0.2	11.
0.5	9.
0.07	5.
0.4	20.
0.4	15.
0.4	18.
0.4	10.
0.4	15.

$c' = c+Q\lambda$	R
0.6	71.
0.4	6.
0.2	31.
0.8	17.
1.2	49.
0.2	19.
0.4	35.

Each row in the above list is a related pair of observations taken at the same location and time. A regression analysis was performed to obtain a least squares fit of the line $R = fc' + e$ to the above data. The result was:

$f = 62.333$

$e = 4.202$

correlation coefficient = .912

t statistic for correlation coefficient = 15.1.

The regression constant e was assumed not significant. The excellent correlation indicates that the formula $R = fg(c + Q\lambda)$ for fallout rate is valid.

The value 62.333 was used for f_2 in the simulation for the MV 67; the variation in this parameter was included in the distributions for c and Q due to the method used to derive the latter two parameters.

Surface Retention Factor, g.

In a study performed at Martin-Marietta, the accumulation of organisms on sterile coupons of various materials was studied. Eight 1" x 2" coupons of each material were exposed for (non-overlapping) periods of 24, 48, 72, 96, 120 and 144 hours to air in the factory area. Half of each set of 8 was treated with an anti-static coating before exposure.

Materials used were:

stainless steel, vapor honed
stainless steel, grit blasted
stainless steel, electro-polished
stainless steel, plain
aluminum, plain
aluminum, Rokide
mylar
silicone rubber
teflon
polycarbonate
phenolic.

Since no significant difference in burden occurred between the various materials and surface treatments, the surface retention factor, g, was assumed independent of surface materials for the MV 67. Furthermore, since g was not significant, it was absorbed in f by setting $g = 1$ throughout.

Work Surface Retention Factor, S_1

A conservative value of 0.8 was used for this parameter, and the following histogram was used for the spread:

Work Surface Retention Factor, S_1

		.12	.16	.24	.28	.20
	.4	.6	.7	.8	.9	1.0

Tool or Hand Retention Factor, S_2

A conservative value of 0.2 was used for this parameter, and the following histogram was used for the spread:

Tool or Hand Retention Factor, S_2

		.20	.28	.24	.16	.12
	0.	.1	.2	.3	.4	.6

Operation Performance Times

For Phase V, performance times were uncertain and hence were represented in histogram form, with a spread of - 20%, + 50% about the nominal:

Basic Time Distribution, t				
		.6	.32	.08
	.8	1.0	1.2	1.5

This basic "shape" was modified to have the proper mean time whenever it was used.

For Phase VI, the times were known, so a constant histogram was used.

Burden on Hands or Tools, b_t

A conservative value of 2000 vegetative organisms/sq ft (200 spores/sq ft) was used for this burden. The distribution for this parameter was obtained from Reference 7 for stainless steel strips handled by various persons (no gloves). Since these strips were initially sterile, the resulting assay was assumed to represent B in the contact formula: $B = (1 - \frac{aS_2}{2A})B_o + \frac{aS_1}{2} b_t$ with $B_o = 0$, $a = A = \frac{1}{36}$ (both sides of 1" x 2" strip), $S_1 = .8$, $S_2 = .2$. This implies that $b_t = 2.5\ B'$, so the 17 assays were multiplied by 2.5 to get: 1710, 990, 1350, 6840, 270, 1980, 2790, 3240, 1710, 4680, 4500, 990, 450, 90, 90, 2430, 2700, organisms/sq ft. The resulting histogram was:

Burden on Hands or Tools, b_t						
	.11765	.05882	.17647	.41177	.17647	.05882
31.6	100.	316.	1000.	3160.	6000.	10000.

Abbreviated version of the b_t Histogram.					
	.17647	.17647	.41177	.17647	.05882
31.6	316.	1000.	3160.	6000.	10000.

Open Transit Environment

It was originally felt necessary to derive histograms to represent burden accumulation in generally open areas. Since the MV67 was carefully covered whenever it was moved between buildings, these histograms were not used in the simulations. They are presented here to supply data for future use of the burden prediction model.

At Martin Marietta, Denver Division, a study was performed to determine (among other things) the microbial burden that accumulated on a Voyager type capsule bus during assembly. This Technology Feasibility Study (TFS) included construction of a full-sized, fairly detailed model of the Martin Marietta Voyager design and periodic microbiological assays of the exposed surfaces. Since the construction was in an ordinary factory area with a large door open to the outside air much of the time, the resulting assays were regarded as representative of open areas.

The following burden histograms were prepared from swab sample (4 sq") assays of both horizontal and vertical surfaces, taken on July 27, 1967. (The data for horizontal and vertical surfaces did not differ significantly.)

TFS Vegetative Aerobes (53 sample points)

	.1132	.2075	.1321	.1321	.0755	.0566	.1132	.0943	.0377	.0377
0.00	1.08	2.16	3.24	4.32	5.40	6.48	10.8	21.6	32.4	108.

TFS Aerobic Spores (54 sample points)

	.5185	.1667	.1481	.0741	.0185	.0370	.0185	.0000	.0185
0.00	1.08	2.16	3.24	4.32	5.40	6.48	7.56	8.64	10.8

(These burdens are in thousands of organisms.)

B. PHASE V

In Phase V, a simulation of the planned assembly and test sequence for the Mariner Venus 67 spacecraft was prepared and used by the microbial burden prediction model to predict the burden on the MV-67. Details of the assembly sequence were obtained from Mariner Venus 1967 Spacecraft Assembly (Ref 4). Test procedures were determined from Mariner Venus 1967 Test and Operations Plan (Ref 5) and Mariner Venus 1967 System Test and Operations Report (Ref 6). The test activities were integrated with assembly activities to give the complete sequence, the major activities of which are presented in Table 4.

The activities in Table 4 were judged to represent a level of detail between a stage and a task, so that each was divided into a number of tasks. These tasks generally correspond to "steps" in Reference 4. The activities in References 5 and 6 are not described by steps, but a corresponding level of detail was selected.

Each task was then detailed to the subtask level. The appropriate subtasks generally correspond to details specifically mentioned in References 4, 5, and 6, although in some cases additional detail was inferred from the nature of the activities being performed. The subtasks that were identified are listed in Table 5.

Each of the subtasks was divided into a number of the generic operations listed in Table 6. Selection of the operations that composed a given subtask was based on the subtask description and on comparison with similar subtasks identified in the generalized assembly and test sequence generated in Phase I of this contract.

The analysis of a small portion of the MV 67 assembly and test sequence is shown in Table 7; the complete sequence appears in Appendix 1 of Vol. V.

Table 4 Mariner Venus 67 Spacecraft Planned Assembly and Test Sequence

I PASADENA OPERATIONS

1 OCTAGON AND SUPERSTRUCTURE PREPARATION
2 INSTALLATION OF THE ATTITUDE CONTROL GAS(ACG) SUBSYSTEM
3 ADJUSTMENT OF THE ACG SUBSYSTEM BELLEVILLE SPRINGS
4 INSTALLATION OF THE UPPER RING HARNESS AND PYROTECHNICS HARNESS
5 INSTALLATION OF THE LOWER RING HARNESS
6 INSTALLATION OF THE PYROTECHNICS ARMING SWITCH (PAS)
7 INSTALLATION OF THE SEPARATION-INITIATED TIMER (SIT)
8 INSTALLATION OF THE SUN GATE
9 INSTALLATION OF THE PRIMARY SUN SENSORS
10 INSTALLATION OF THE PLASMA PROBE
11 INSTALLATION OF THE POSTINJECTION PROPULSION SUBSYSTEM (PIPS)
12 ADJUSTMENT OF THE PIPS BELLEVILLE SPRINGS
13 INSTALLATION OF THE LOW-GAIN ANTENNA AND ASSOCIATED DAMPERS
14 INSTALLATION OF THE HIGH-GAIN ANTENNA AND APAC MECHANISM
15 INSTALLATION OF THE MAGNETOMETER SENSOR AND CABLING
16 INSTALLATION OF THE SECONDARY SUN SENSORS
17 INSTALLATION OF THE EARTH SENSOR
18 ASSEMBLY AND INSTALLATION OF EA I (POWER SUBSYSTEM)
19 ASSEMBLY AND INSTALLATION OF EA III (SCIENCE SUBSYSTEM)
20 ASSEMBLY AND INSTALLATION OF EA IV (DATA ENCODER AND COMMAND SUBSYSTEMS)
21 ASSEMBLY AND INSTALLATION OF EA V (RADIO AND TAPE RECORDER)
22 BUILDUP AND INSTALLATION OF EA VI (RADIO SUBSYSTEM)
23 BUILDUP AND INSTALLATION OF EA VII (ATTITUDE CONTROL AND CENTRAL COMPUTER AND SEQUENCER SUBSYSTEMS)
24 BUILDUP AND INSTALLATION OF EA VIII (POWER SUBSYSTEM)
25 INSTALLATION OF THE TRAPPED-RADIATION DETECTOR
26 INSTALLATION OF THE CANOPUS SENSOR
27 INSTALLATION OF THE PLANET SENSOR
28 INSTALLATION OF THE TERMINATOR SENSOR
29 INSTALLATION OF THE UV PHOTOMETER
30 INSTALLATION OF THE TEMPERATURE CONTROL LOUVERS
31 INSTALLATION OF THE THERMAL SHIELDS
32 INSTALLATION OF THE THERMAL BLANKETS
33 INSTALLATION OF THE SOLAR PANELS AND ASSOCIATED EQUIPMENT
34 THERMAL CONTROL WRAPPING OF SPACECRAFT ELECTRICAL CABLES
35 PREPARATION OF THERMAL CONTROL SURFACES
36 SPACECRAFT - STC INTERFACE TEST
37 POWER SUBSYSTEM TEST
38 INITIAL POWER APPLICATION
39 SUBSYSTEM INTERFACE TESTS
40 SUBSYSTEM TESTS
41 SYSTEM TEST
42 FREE MODE TEST (PART I)
43 FREE MODE TEST (PART II)
44 WEIGHT AND CENTER OF GRAVITY MEASUREMENT
45 SIMULATED COUNTDOWN
46 SPACECRAFT - AGENA INTERFACE TEST

Table 4 (Continued)

47 PYROTECHNICS SHOCK TEST
48 SPACECRAFT MOS OPERATIONAL TEST
49 SYSTEM TEST
50 VIBRATION TEST
51 SYSTEM VERIFICATION TEST
52 SPACE SIMULATOR TEST
53 SYSTEM VERIFICATION TEST
54 SPACECRAFT DISASSEMBLY (PARTIAL)
55 SUBASSEMBLY DEGAUSSING
56 FINAL INSPECTION
57 SPACECRAFT RE-ASSEMBLY
58 ATTITUDE CONTROL GAS SUBSYSTEM GAS LEAK TEST
59 MAGNETOMETER MAPPING
60 CURRENT LOOP TESTS
61 PRE-SHIPMENT SYSTEM TEST
62 SPACECRAFT SHIPMENT PREPARATION
63 SPACECRAFT SHIPMENT TO THE EASTERN TEST RANGE

II EASTERN TEST RANGE OPERATIONS

1 SPACECRAFT BUILDUP VERIFICATION AT HANGAR AO
2 SPACECRAFT RE-ASSEMBLY
3 SYSTEM VERIFICATION TEST
4 CALIBRATION VERIFICATION TEST
5 PRE-LAUNCH SYSTEM TEST
6 SPACECRAFT SHIPMENT PREPARATION AT HANGAR AO
7 SPACECRAFT TRANSPORTATION FROM BLDG AO TO ESF
8 ATTITUDE CONTROL GAS LEAK TEST
9 ELECTRICAL TEST
10 LIVE PRYOTECHNICS INSTALLATION
11 PIPS INSTALLATION
12 FINAL SPACECRAFT ASSEMBLY
13 SPACECRAFT - AGENA MATING (ADAPTER AND SHROUD)
14 SPACECRAFT SHIPMENT PREPARATION FROM ESF

Table 5 Subtask Catalog, Planned Sequence

1.1	MANEUVER EQUIPMENT
1.2	ATTACH EQUIPMENT
1.3	TRANSPORT EQUIPMENT
1.4	DETACH EQUIPMENT
2.1	MANEUVER SPACECRAFT
2.2	ATTACH SPACECRAFT
2.3	TRANSPORT SPACECRAFT
2.4	DETACH SPACECRAFT
2.5	INSPECT SPACECRAFT
3.1	MANEUVER SUBSYSTEM
3.2	ATTACH SUBSYSTEM
3.3	TRANSPORT SUBSYSTEM
4.1	MANEUVER (SMALL HARDWARE)
4.2	TRANSPORT (SMALL HARDWARE)
4.3	INSPECTION (SMALL HARDWARE)
4.4	SUBSYSTEM COMPONENT PLACEMENT
4.7	ROUTE HARNESSES (CABLES, HOSES, ETC)
4.8	INSTALL BASIC HARDWARE (SCREWS, BRACKETS, ETC)
4.9	REMOVE BASIC HARDWARE (SCREWS, BRACKETS, ETC)
4.10	TENSION CABLES
4.11	VACUUM CLEAN HARDWARE
4.12	ATTACH EQUIPMENT (HANDLING FRAMES, ETC)
4.13	DETACH EQUIPMENT (HANDLING FRAMES, ETC)
4.14	REMOVE HARDWARE FROM SHIPPING CONTAINER
4.18	INSTALL SUBASSEMBLY IN MODULE
4.19	REMOVE SUBASSEMBLY FROM MODULE
4.20	INSTALL SUBASSEMBLY IN MODULE
4.21	REMOVE SUBASSEMBLY FROM MODULE
4.22	CONNECT HARNESSES (CABLES, HOSES, ETC)
4.23	SUBSYSTEM COMPONENT DETACHMENT
4.24	SUBSYSTEM COMPONENT REMOVAL
4.25	SENSOR CONTINUITY CHECK
5.1	MANEUVER (SMALL HARDWARE)
5.2	TRANSPORT (SMALL HARDWARE)
5.3	INSPECTION (SMALL HARDWARE)
5.4	SUBSYSTEM COMPONENT PLACEMENT
5.5	SUBSYSTEM COMPONENT ATTACHMENT
5.6	SUBSYSTEM COMPONENT INTERCONNECTION
5.7	ROUTE HARNESSES (CABLES, HOSES, ETC)
5.8	INSTALL BASIC HARDWARE (SCREWS, BRACKETS, ETC)
5.9	REMOVE BASIC HARDWARE (SCREWS, BRACKETS, ETC)
5.12	ATTACH EQUIPMENT (HANDLING FRAMES, ETC)
5.13	DETACH EQUIPMENT (HANDLING FRAMES, ETC)
5.14	REMOVE HARDWARE FROM SHIPPING CONTAINER
5.15	MOUNT HARDWARE IN SHIPPING CONTAINER
5.16	VERIFY TORQUE VALUES
5.17	ADJUST SPRINGS
5.18	INSTALL MODULE (EA I, ETC) IN SPACECRAFT

Table 5 (Continued)

5.19	REMOVE MODULE (EA I, ETC) FROM SPACECRAFT
5.22	CONNECT HARNESSES (CABLES, HOSES, ETC)
5.23	SUBSYSTEM COMPONENT DETACHMENT
5.24	SUBSYSTEM COMPONENT REMOVAL
5.25	SENSOR CONTINUITY CHECK
5.26	ANTENNA ALIGNMENT
5.27	ANTENNA ADJUSTMENT
5.28	ANTENNA DEPLOYMENT
5.29	WRAP HARNESSES (CABLES, HOSES, ETC)
5.30	SOLDER LEADS
5.31	ELECTRICAL FIT CHECK
6.1	MANEUVER (SMALL HARDWARE)
6.2	TRANSPORT (SMALL HARDWARE)
6.4	SUBSYSTEM COMPONENT REMOVAL
6.5	SUBSYSTEM COMPONENT DETACHMENT
6.6	SUBSYSTEM COMPONENT DISCONNECTION
6.7	PULL HARNESSES (CABLES, HOSES, ETC)
6.8	INSTALL BASIC HARDWARE (SCREWS, BRACKETS, ETC)
6.9	REMOVE BASIC HARDWARE (SCREWS, BRACKETS, ETC)
6.10	TENSION CABLES
6.11	SUBSYSTEM COMPONENT PLACEMENT
6.12	ATTACH EQUIPMENT (HANDLING FRAMES, ETC)
6.13	DETACH EQUIPMENT (HANDLING FRAMES, ETC)
6.14	REMOVE HARDWARE FROM SHIPPING CONTAINER
6.17	MOUNT HARDWARE IN SHIPPING CONTAINER
6.18	INSTALL MODULE (EA I, ETC) IN SPACECRAFT
6.19	REMOVE MODULE (EA I, ETC) FROM SPACECRAFT
6.22	CONNECT HARNESSES (CABLES, HOSES, ETC)
7.1	CONNECT EQUIPMENT
7.2	REMOVE COVERS
7.3	CONN SUBSYS/OSE
7.4	MECHANICAL INSPECTION
7.5	INSTALL EQUIPMENT (ACCELEROMETERS, ETC)
7.6	REMOVE EQUIPMENT (ACCELEROMETERS, ETC)
7.7	ROUTE CABLES (HARNESSES, HOSES, ETC)
7.8	INSTALL HARDWARE IN DEGAUSSING CHAMBER
8.1	PERFORM TEST
8.3	DEMATE CONNECTOR
8.4	PERFORM CONTINUITY CHECK
8.5	MATE CONNECTOR
8.6	VOLT/NO VOLT TEST
8.7	OPEN CIRC MEAS
8.8	MANEUVER (SMALL HARDWARE)
8.9	INSTALL BASIC HARDWARE (SCREWS, BRACKETS, ETC)
8.10	REMOVE BASIC HARDWARE (SCREWS, BRACKETS, ETC)
8.11	CALCULATE SPACECRAFT CENTER-OF-GRAVITY
8.12	DEGAUSS HARDWARE
9.1	DISCONNECT EQUIPMENT

Table 5 (Continued)

9.2	INSTALL COVERS
9.3	DISCONN SUBSYS/OSE
9.4	INSTALL EQUIPMENT (ACCELEROMETERS, ETC)
9.5	REMOVE EQUIPMENT (ACCELEROMETERS, ETC)
9.7	PULL CABLES (HARNESSES, HOSES, ETC)
9.8	REMOVE HARDWARE FROM DEGAUSSING CHAMBER
9.9	MANEUVER (SMALL HARDWARE)
9.10	REMOVE BASIC HARDWARE (SCREWS, BRACKETS, ETC)
10.1	POSITION HARDWARE
10.2	INSTALL BASIC HARDWARE (SCREWS, BRACKETS, ETC)
10.3	REMOVE BASIC HARDWARE (SCREWS, BRACKETS, ETC)
10.4	ROUTE FILL LINES
10.5	CONNECT FILL LINES
10.6	PRESSURIZE SYSTEM
10.7	REMOVE HARDWARE
10.8	TRANSPORT HARDWARE

Table 6 Assembly Operations Used in the Phase V and VI Simulations

1	Manipulate by Hand
2	Manipulate with Tools
3	Move w/Crane
4	Drill, File, etc.
5	Move in Handling Frame
6	Wipe (Clean or Assay)
7	Vacuum Clean
8	Solder (Unsolder)
9	Visual Inspection
10	Inspection with Gauges
11	Mate (Demate) Connectors
12	Potting, Painting
13	Use Flux Tank
14	Tie Harnesses
15	Maneuver Equipment
16	Maneuver Spacecraft
17	Secured in Tent

Table 7 Example of Phase V Functional Analysis

From Reference 4 (p 17):

A. Octagon and Superstructure Preparation

Step 1 Position laminar flow tent to allow movement of octagon to low-level positioner with spacecraft lifting fixture per JPL Proc MV67 102 and place octagon on low-level positioner.

Resulting sequence:

Stage 1	ASSEMBLY AND TEST, PASADENA OPERATIONS
Task 1	POSITION LAMINAR FLOW TENT
Subtask 1	1.1 MANEUVER LF TENT
Operation 1	15 MANEUVER EQUIPMENT
Task 2	PLACE OCTAGON ON LOW-LEVEL POSITIONER
Subtask 1	2.3 TRANSPORT OCTAGON
Operation 1	3 MOVE WITH CRANE
Subtask 2	2.1 MANEUVER OCTAGON
Operation 1	1 MANIPULATE BY HAND
Subtask 3	2.2 ATTACH OCTAGON TO LOW-LEVEL POSITIONER
Operation 1	1 MANIPULATE BY HAND
Operation 2	2 MANIPULATE WITH TOOLS
Subtask 4	2.5 INSPECT OCTAGON
Operation 1	9 VISUAL INSPECTION

Note: The numbers appearing with the subtask and operation descriptions are merely for identification; see Tables 6 and 7.

The activities in this list were assumed to be performed sequentially although in many cases it would have been possible to perform several activities concurrently.

During the derivation of the assembly and test sequence, a list of spacecraft hardware was maintained. This list (Table 8) includes all hardware except screws, washers, and similar small items. The dimensions of each identified part were obtained from JPL and used to calculate the surface areas. The resulting areas are included in Table 8.

The MV67 was divided into zones, each of which was assumed to represent a region of nearly uniform burden accumulation. These zones were selected to correspond to discrete hardware units (Table 9).

The microbial burden prediction model maintains separate burden histograms for each of four surfaces (top exterior, other exterior, mated, and occluded). However, only two of these surfaces were used for MV67. Surface two was used for all exterior surfaces because it was assumed that the frequent spacecraft reorientation made the distinction between top and other exterior surfaces unimportant. Surface four was not used because it was assumed that no occluded surfaces were initially present and that none were generated during the assembly.

References 4, 5, and 6 did not specify the number of men and the time required to perform the assembly and test activities so these were determined from the JPL QA Spacecraft Daily Activity Report for the MV 67 (Ref 2) and

Table 8 Hardware List

	AREA (SQ FT) EXTERNAL	MATED
OCTAGON	67.8400	.0000
SHEAR PLATE	5.0660	.1000
PLASMA PROBE BRACKET	.1250	.0150
JET VALVE ASSY	.4444	.0450
GAS TUBING LINES	.5891	.0005
NITROGEN BOTTLE SUPPORT	.0833	.0067
BELLEVILLE SPRINGS	.1597	.0200
BOTTLE BRACKET	.2500	.0355
APAC PYRO HARNESS	.1963	.0005
CABLE(9W38P3)	.0982	.0001
CABLE(9W38P5)	.0982	.0001
CABLE(9W38P7)	.0982	.0001
APAC SQUIB HARNESS	.3927	.0008
CABLE(4A1P1)	.0436	.0003
CABLE(4A3P1)	.0436	.0003
CABLE(4A5P1)	.0436	.0003
CABLE(4A7P1)	.0436	.0003
DFR FILTER	.0654	.0045
DFR FILTER	.0654	.0045
CABLE, COAX(15W2)	.2291	.0005
CABLE, COAX(15W9)	.1636	.0005
INFLT DISCONN CONNECTOR	.1111	.0012
LOWER RING HARNESS	1.5710	.0050
CABLE, ACCELEROMETER	.0982	.0003
CABLE, SUN SENSOR	.1309	.0003
CABLE, SUN SENSOR	.1309	.0003
CABLE, MOTION SENSOR	.1527	.0003
CABLE, COAX(15W1)	.0982	.0003
CABLE, SUN GATE	.1309	.0003
CABLE, RADIO COAX	.0982	.0003
PYRO ARMING SWITCH	.1146	.0208
SEP-INIT TIMER	.3646	.0050
PEDESTAL COVERS	.3382	.0299
SUN GATE ASSY	.1146	.0089
PRIMARY SUN SENSOR	.2049	.0243
PLASMA PROBE	.5236	.1936
CABLE, PAS CONNECTOR	.1309	.0003
CABLE, SIT CONNECTOR	.1309	.0003
CABLE, COAX	.1636	.0005
MIDCOURSE SHEAR PLATE	5.0940	1.0500
MIDCOURSE MOTOR (PIPS)	8.0670	1.0000
HINGE BOX	.1111	.0100
LOW-GAIN ANTENNA	8.7380	.1104
ANT SUPP BRACKET	.3507	.0444
LONG DAMPER	.0982	.0031
CABLE, ANTENNA	.0545	.0003
SHORT DAMPER	.0982	.0010

Table 8 (continued)

	AREA (SQ FT) EXTERNAL	MATED
HINGE BRACKETS	.0234	.0005
ANT MOUNTING BRACKETS	.3507	.0420
LATCH BRACKET	.0234	.0010
HIGH-GAIN ANTENNA	21.1806	.0347
ANTENNA STOP ARM	.0305	.0005
MAGNETOMETER THERM SHLD	.7639	.0688
MAGNETOMETER SENSOR	.8681	.0139
MAGNETOM SIG HARNESS	.3927	.0003
CABLE LOOP	.1309	.0003
SECONDARY SUN SENSOR	.2049	.0243
EARTH SENSOR	.1111	.0139
CABLE, EARTH SENSOR	.0982	.0003
CHASSIS ASSY(EA I)	8.1670	.8233
S/A, EA I(DUMMY INVERT)	.9167	.2500
S/A, EA I(POWER SYNC)	.9167	.2500
S/A, EA I(POWER DISTRIB)	.9167	.2500
S/A, EA I(MANEUV INVERT)	1.0420	.2500
S/A, EA I(PYRO CONTROL)	1.0420	.2500
S/A, EA I(MAIN INVERTER)	1.0420	.2500
S/A, EA I(BATT CHARGER)	1.0420	.2500
S/A, EA I(3-PHASE INVER)	.9167	.2500
EA I CASE HARN ASSY	.2618	.0003
CHASSIS ASSY(EA III)	8.1667	.8233
S/A, EA III(PLASMA ELEC)	.9167	.2500
S/A, EA III(PLASMA ELEC)	.9167	.2500
S/A, EA III(PLASMA ELEC)	.9167	.2500
S/A, EA III(D/F ELECT)	1.1670	.2500
S/A, EA III(D/F ELECT)	1.1670	.2500
S/A, EA III(MAG ELECT)	1.0420	.2500
S/A, EA III(MAG ELECT)	1.0420	.2500
S/A, EA III(POWER CONV)	1.0420	.2500
S/A, EA III(DAS LOG EL)	.9167	.2500
S/A, EA III(DAS LOG EL)	.9167	.2500
S/A, EA III(DAS LOG EL)	.9167	.2500
S/A, EA III(DAS LOG EL)	.9167	.2500
S/A, EA III(DAS LOG EL)	.9167	.2500
S/A, EA III(DAS LOG EL)	.9167	.2500
S/A, EA III(DAS LOG EL)	.9167	.2500
S/A, EA III(DAS LOG EL)	.9167	.2500
S/A, EA III(UV PHOTO EL)	.7667	.2500
EA III CASE HARN ASSY	.6981	.0008
INTERCONN HARN ASSY	.0109	.0003
CHASSIS ASSY(EA IV)	8.1667	.8233
S/A, EA IV(NOISE GENER)	.9167	.2500
S/A, EA IV(A-D CONV)	.9167	.2500
S/A, EA IV(DATA ENCODER)	.9167	.2500
S/A, EA IV(EVENT CNTER)	.9167	.2500

Table 8 (continued)

	AREA (SQ FT) EXTERNAL	MATED
S/A, EA IV(FUNCT SWIT)	.9167	.2500
S/A, EA IV-DECKS 100/110	.9167	.2500
S/A, EA IV-DECKS 210/220	.9167	.2500
S/A, EA IV-DECKS 200/300	.9167	.2500
S/A, EA IV-DECKS 400/410	.9167	.2500
S/A, EA IV-DECKS 420/430	.9167	.2500
S/A, EA IV-LOW LEVEL AMP	.9167	.2500
S/A, EA IV(POWER SUPPLY)	1.0420	.2500
S/A, EA IV(COMM DETECT)	.7667	.2500
S/A, EA IV(COMM DETECT)	.7667	.2500
S/A, EA IV(COMM DETECT)	.7667	.2500
S/A, EA IV(PROG CONTROL)	.7667	.2500
S/A, EA IV(COMM DECODER)	.7667	.2500
S/A, EA IV(COMM DECODER)	.7667	.2500
S/A, EA IV(COMM DECODER)	.7667	.2500
EA IV HARNESS ASSY	.3491	.0033
CHASSIS ASSY(EA V)	8.1670	.8233
S/A, EA V(RECEIVER)	1.1670	.2500
S/A, EA V(RECEIVER)	1.1670	.2500
S/A, EA V(TAPE RECORDER)	1.8333	.2500
S/A, EA V(TAPE ELECT)	.9167	.2500
S/A, EA V(TAPE ELECT)	.9167	.2500
S/A, EA V(TAPE ELECT)	1.0420	.2500
S/A, EA V(TAPE ELECT)	.7667	.2500
S/A, EA V(XFORM/RECTIF)	.7667	.2500
EA V CASE HARN ASSY	.3491	.0003
CHASSIS ASSY(EA VI)	8.1670	.8233
CHASSIS ASSY(EA VII)	8.1670	.8233
S/A, EA VII(CONT ELECT)	2.5830	.2500
S/A, EA VII-CENTRAL CLOC	.7667	.2500
S/A, EA VII-LAUNCH CNTER	.7667	.2500
S/A, EA VII-END COUNTER	.7667	.2500
S/A, EA VII-MANEUV CLOCK	.7667	.2500
S/A, EA VII-MANEUV DURAT	.7667	.2500
S/A, EA VII-REGULATOR	.7667	.2500
S/A, EA VII-INPUT DECOD	.7667	.2500
S/A, EA VII-CCS XFORMER	.7667	.2500
S/A, EA VII-CCS REL HOLD	1.0830	.2500
EA VII HARNESS ASSY	.3491	.0055
CONTROL GYRO	1.5830	.2550
BATTERY-4A14(EA VIII)	5.8400	1.8889
CANOPUS SENSOR	2.0140	.4167
CANOPUS SENS BAFFLE HOOD	1.3190	.2431
PLANET SENSOR	.2618	.0218
TERMINATOR SENSOR	.1309	.0055
TRAPPED RAD DETECTOR	1.0280	.2083
UV PHOTOMETER	2.5690	.5556

Table 8 (continued)

	AREA (SQ FT)	
	EXTERNAL	MATED
UPPER SCI SIG HARNESS	.0982	.0003
LOUVER CASE(BAY I)	4.2360	1.8889
LOUVER CASE(BAY III)	4.2360	1.8889
LOUVER CASE(BAY IV)	4.2360	1.8889
LOUVER CASE(BAY V)	4.2360	1.8889
LOUVER CASE(BAY VI)	4.2360	1.8889
LOUVER CASE(BAY VII)	4.2360	1.8889
LOUVER CASE(BAY VIII)	4.2360	1.8889
LOUVERS(132)	22.6400	.0000
CABLE TROUGH BLANKET	4.3610	.0000
UPPER CHAN SHLD-BAY 1	.1854	.0380
UPPER CHAN SHLD-BAY 1V	.1854	.0380
UPPER CHAN SHLD-BAY V	.1854	.0380
UPPER CHAN SHLD-BAY VI	.1854	.0380
UPPER CHAN SHLD-BAY VII	.1854	.0380
UPPER CHAN SHLD-BAY VIII	.1854	.0380
UPPER THERMAL BLANKET	28.3300	.0000
PEDESTAL BLANKET	.5000	.0000
LOWER THERMAL BLANKET	28.3300	.0000
THERMAL SHIELD BLANKET	.0069	.1000
BAY I SOLAR PANEL	27.9900	1.6667
BAY III SOLAR PANEL	27.9900	1.6667
BAY V SOLAR PANEL	27.9900	1.6667
BAY VII SOLAR PANEL	27.9900	1.6667
SOL PAN SQUIB HARNESS	.8727	.0008
BOOST DAMPER	.0654	.0100
SPAR THERMAL SHIELD	.1250	.0035
ANT COAX CABLE	.4363	.0005
DFR ANTENNA(423 MHZ)	.7636	.0014
DFR ANTENNA(49.8 MHZ)	1.3744	.0491
SOL PAN DEPLOY MECHANISM	.2778	.0028
CRUISE DAMPER	.2917	.0417
PANEL SUPPORT STRUT	.1492	.0009
FLIGHT NOZZLE	.0041	.0008
EAGLE SHIELD-BAY IV	3.7890	.0300
TRD SHADE BLANKET	.5000	.2083
UMB THERMAL SHIELD	.1667	.0100
CORNER SHIELD	.9517	.4722
SUN SHADE	40.83	.0694
ATTENUATORS	.2083	.0010
ACCELEROMETER	.0417	.0003
TRANSDUCER	.0986	.0003
DISC COVER	1.0000	.0020
BRACKETS	.1000	.0100
PLATE RING	.5000	.0155
TANK PLATE	2.0000	.5000
APAC PYRO PIN	.4375	.0450
LIVE SOL PANEL PIN	.4375	.0450
BAFFLE BOX	1.3194	.2431
TEMP CONT REFERENCE	.0600	.0100

Table 9 Zone Definitions

Zone	Zone Definition
1	Bay I (outward facing from bay mounting plate)
2	Bay II
3	Bay III
4	Bay IV
5	Bay V
6	Bay VI
7	Bay VII
8	Bay VIII
9	Bay I (inward facing from bay mounting plate)
10	Bay II
11	Bay III
12	Bay IV
13	Bay V
14	Bay VI
15	Bay VII
16	Bay VIII
17	Solar Panel I
18	Solar Panel III
19	Solar Panel V
20	Solar Panel VII
21	Solar Panel I Spar
22	Solar Panel III Spar
23	Solar Panel V Spar
24	Solar Panel VII Spar
25	Hi-gain Antenna Assembly
26	Lo-gain Antenna Assembly
27	Top Ring Harness Tray
28	Bottome Ring Harness Tray
29	Ground Antenna Assembly
30	Upper Ring Harness Assembly
31	Lower Ring Harness Assembly
32	EA III Harness Assembly
33	EA IV Harness Assembly
34	EA V Harness Assembly
35	EA VI Harness Assembly
36	EA VII Harness Assembly
37	EA VIII Harness Assembly
38	EA I Harness Assembly
39	Leg A
40	Leg B
41	Leg C
42	Leg D
43	Leg E
44	Leg F
45	Leg G

Table 9 (Continued)

Zone	Zone Definition
46	Octagon Top
47	Octagon Bottom
48	Octagon, Side
49	EA I Case
50	EA III Case
51	EA IV Case
52	EA V Case
53	EA VI Case
54	EA VII Case
55	EA VIII Case
56	Leg H
57	Not Used
58	Shroud

the bio parameter supplement (Ref 3). The work was simulated as being performed on an 8 hour day, 40 hour week by inserting operation 17, "Secured in Tent" at the end of each eight hours of activity in the assembly and test sequence. All times are represented as histograms for the Phase V simulation since these times were estimated. The basic histogram (which when used is modified to have the correct mean value) includes a variation of +50%, -20% about the nominal:

Basic Time Histogram				
		.6	.32	.08
	.8	1.0	1.2	1.5

The microbial burden prediction model data input deck was prepared according to the details of the assembly and test sequence; Appendix 1 of Volume V lists the complete sequence including the hardware affected by each operation. Numerical values used for the biological parameters (e.g., burden on hands and tools) were those derived in Phase IV.

Changes in assembly environment were determined from References 1 and 2. Area changes during assembly (e.g., increase of mated area and corresponding decrease in exterior area due to joining two parts) were based on the surface areas calculated for each part. The area touched by personnel or tools was estimated from the nature of the activity being performed and from the exterior surface area of the part.

After the data card errors had been identified by the Data Check Program and corrections made, the first simulation revealed a fault in the method used in the computer to perform arithmetic operations on histograms. After many thousands of such operations, the resulting burden histograms had all of the probability in the uppermost interval; for example:

	0.0	0.0	0.0	0.0	1.0
0.	300.	1200.	6500.	41000.	2,000,000.

This fault was not revealed by the test case run in Phase III for two reasons:

1) The historgrams arbitrarily chosen for the test case did not have the extreme variability present in the historgrams derived from actual assays;

2) The error grows very slowly; it does not appear in test cases having only a few hundred operations.

Although the resulting burden histograms were correct, they were nearly useless for statistical work. The microbial burden prediction model was therefore changed to guarantee that each burden histogram makes use of all available intervals; a special distribution is input specifying the probability of each interval, and this is used each time the burden is printed. For example, the previous histogram would become

	0.3	0.5	0.1	0.09	0.01
0.	50,000.	100,000.	300,000.	500,000.	2,000,000.

The simulation was repeated after the correction had been made, and another fault was discovered. When the burden predictions were compared to assays of the hardware, it was found that the burden prediction was too large by a factor of about 60. This was found to be due to the fact that when two burden histograms were multiplied, the mean value of the product was greater than the product of the means of the two original historgrams. Thus, when the burden prediction formulas were applied to histograms, the results were considerably different than when constants were used. The computer program was changed to include an adjustment of the calculated burden histogram to agree (in mean value) with the result that would have been obtained using constants instead of histograms. This adjustment is accomplished by multiplying interval values of the histogram by the factor $\frac{\text{correct mean value}}{\text{actual mean value}}$; the shape of the histogram is not altered by this adjustment.

C PHASE VI

In Phase VI, a simulation of the actual assembly and test sequence for Mariner Venus 67 was performed. Details of this sequence were obtained from the daily activity logs (References 2 and 3), which were followed almost exactly. In some cases a series of log entries was gouped under a single activity because they were identical as far as the burden accumulation model was concerned (e.g., a series of vibration tests).

The activities obtained from the logs were regarded as subtasks; the operations into which each of these subtasks was divided were chosen on the basis of the subtask description as in Phase V. The generic operations used in Phase VI were the same as for Phase V (Table 6). Organization of the subtasks into tasks was not practical since several unrelated activities were usually in progress concurrently; thus any unified tasks that could have been identified (e.g., install solar panel, Bay V) would have had their subtasks scattered through several pages of entries in the log. Therefore, each group of approximately 20 log entries was arbitrarily made into a "task" labeled "Mechanical Assembly and Test". (The microbial burden prediction model requires the use of tasks, however arbitrary, since these control the reading of certain input data, e.g., parts lists.)

Two stages were assigned, separating the assembly and test sequence into Pasadena operations and ETR operations.

The simulated sequence for a small portion of the MV 67 assembly and test sequence is shown in Table 10; the complete sequence appears in Appendix 2 of Vol. V.

Table 10 Example of Phase VI Activities

From References 2 and 3 (12 December 1966)

Time	Activity
0830	Technicians drill, tap and install two Pressnuts into Octagon. Vacuum clean. (2 hours)
-	Locate and drill one hole. Vacuum clean. (30 min)
1300	Locate, drill, and rivet two filters in place. Vacuum clean (90 min)
-	S/C under N_2 Purge at night (16 hours)

Resulting Sequence:

Stage 1	ASSEMBLY AND TEST, PASADENA OPERATIONS
Task 1	MECHANICAL ASSEMBLY AND TEST
Subtask 1	INSTALL PRESSURE NUTS (2)
Operation 1	4 DRILL, FILE, etc.
Operation 2	7 VACUUM CLEAN
Operation 3	4 DRILL, FILE, etc.
Operation 4	2 MANIPULATE WITH TOOLS
Subtask 2	INSTALL 2 FILTERS
Operation 1	1 MANIPULATE BY HAND
Operation 2	2 MANIPULATE WITH TOOLS
Operation 3	1 MANIPULATE BY HAND
Operation 4	2 MANIPULATE WITH TOOLS
Subtask 3	S/C SECURED DEC 12-13

Note: The numbers appearing with the operation descriptions are merely for identification; see Table 7.

The hardware list for Phase V (Table 9) was also used for Phase VI; the only difference was in the order in which they were input. The surface areas (exterior and mated) for each part were the same as in Phase V.

The number of men working near the hardware during a given subtask was assumed to be the "People in Area" entry in Reference 3. "Near" is assumed to be within 5 ft. The number of men working on corresponding subtasks of Phases V and VI were therefore the same since both were based on Reference 3. The area contacted by tools or personnel was estimated from the area of the part and from the "People Handle Part" and "Tools Used" entries in Reference 3.

Changes in assembly environment were obtained directly from References 2 and 3. The numerical values used for the biological parameters were those derived in Phase IV.

III RESULTS AND CONCLUSIONS

After the Phase V and Phase VI simulations had been performed, the results were compared to determine the differences betwe ie planned and the actual sequences.

The simulation represented activities performed between December 12, 1966 and May 28, 1967, a total of 4032 hours. The Phase V simulation generated the following histogram for completion time:

	.5104	.4390	.0507
3459.	4323.	5188.	6485.

This histogram can be seen to include the actual number of hours. However, the Phase VI simulation produced a duration of only 3213 hours, a difference of 20%. (In Phase VI the actual times were known, so that time histograms were not used.) The missing time was traced to the fact that Reference 3 did not include entries for [illegible] during which no activity was in progress whereas in preparing the simulation it was assumed that Reference 3 could be followed exactly. The burden prediction is still considered valid (although slightly conservative) since including the omitted times could only reduce the calculated burden.

The simulations performed in Phases V and VI also differed in the total area of assembly:

	Phase V	Phase VI	
Exterior Surface Area	859.5	560.3	sq ft
Mated Surface Area	48.5	53.9	sq ft

The 10% difference in mated area was not considered significant, but the large difference in exterior areas was traced to inclusion of the top and bottom covers, the plastic bag (shroud), and the ring clamp in the total area for Phase V. When these non-flight items had been deducted, the new Phase V area became 581.8 sq ft.

In Phase V and Phase VI separate simulations were performed for:

1) Spores (i.e., heat shocked samples);
2) Vegetative Organisms (i.e., non heat shocked samples).

The burden prediction histograms for the four simulations are presented in Tables 11 and 12. The two simulations for vegetative organisms were performed on a CDC-6500 at Martin Marietta; the two spore simulations were performed at JPL on an IBM 7094-7044 direct couple system. In addition to the different parameter values and initial burdens required for spores, an option in the computer program was exercised to increase the number of histogram intervals from 5 to 10 near the end of both spore simulations.

Comparison of the burden predictions for Phases V and VI indicate differences, but these differences are not great. As mentioned in the Introduction, the contract defines a significant difference as a log (factor of 10). On this basis the burdens predicted by the simulations of Phases V and VI did not differ significantly.

The burden predictions for vegetative organisms differed by a factor of 1.9 for exterior surfaces and 2.4 for mated surfaces, with the Phase V burden being the larger for both surfaces. The factors were determined by comparing corresponding Phase V and Phase VI histograms, (using the Kolmogorov-Smirnov test) and multiplying the smaller by such a factor that the difference was minimized. (This is easily accomplished by graphing the two cumulative probability curves on logarithmic paper and sliding one over the other to obtain the best fit.) The burden difference was attributed to a cleaning operation that

Table 11 Burden Predictions, Spores

Phase V - Planned Sequence										
Exterior (Surface 2), 559 sq ft, Mean Burden 57.8 x 10^3										
	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.05	0.04	0.01
0.00	16.0	27.3	34.0	42.7	55.0	75.2	122.	221.	330.	479.
Mated (Surface 3), 48.5 sq ft, Mean Burden 18.6 x 10^3										
	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.05	0.04	0.01
1.19	11.6	15.7	17.2	18.8	20.8	23.9	29.4	34.7	55.4	106.
Total 608. sq ft, Mean Burden 83.1 x 10^3										
	.153	.215	.110	.116	.109	.104	.099	.052	.038	.008
0.94	27.9	44.5	53.5	65.0	81.0	107.	167.	288.	432.	647.
Phase VI - Actual Sequence										
Exterior (Surface 2), 560. sq ft, Mean Burden 69.7x10^3										
	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.05	0.04	0.01
0.30	29.6	45.0	52.3	62.3	76.5	98.1	141.	196.	262.	440.
Mated (Surface 3), 53.9 sq ft, Mean Burden 9.1x10^3										
	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.05	0.04	0.01
0.49	3.15	5.04	6.08	7.43	9.28	12.1	17.5	25.0	53.7	94.5
Total , 614. sq ft, Mean Burden 79.7 x 10^3										
	.1673	.1910	.1036	.1144	.1129	.1097	.1061	.0544	0329	.0076
0.78	32.8	50.0	58.4	69.7	85.8	110.	158.	221.	315.	535.

Note: All histogram burdens are in thousands of organisms.

Table 12 Burden Predictions, Vegetative Organisms

Phase V - Planned Sequence					
Exterior (Surface 2), 582 sq ft, Mean Burden 7.75 x 10^6					
	0.3	0.5	0.1	0.09	0.01
0.00	4.91	9.87	12.8	27.3	48.3
Mated (Surface 3), 48.5 sq ft, Mean Burden 1.02 x 10^6					
	0.3	0.5	0.1	0.09	0.01
0.00	0.69	1.33	1.66	3.19	5.69
Total 630 sq ft, Mean Burden 8.78 x 10^6					
	.2862	.5142	.1010	.0894	.0092
0.00	5.57	11.1	14.4	30.5	53.9
Phase VI - Actual Sequence					
Exterior (Surface 2), 560. sq ft, Mean Burden 4.06 x 10^6					
	0.3	0.5	0.1	0.09	0.01
0.00	2.56	5.25	6.92	13.6	24.6
Mated (Surface 3), 53.9 sq ft, Mean Burden 0.44 x 10^6					
	0.3	0.5	0.1	0.09	0.01
0.00	0.30	0.57	0.70	1.35	2.43
Total, 614 sq ft, Mean Burden 4.52 x 10^6					
	.2854	.5150	.1018	.0886	.0092
0.00	2.85	5.82	7.62	15.0	27.0

Note: All histogram burdens are in millions of oranisms.

was performed in Phase VI but not in Phase V.

The burden predictions for spores produced somewhat different results. Comparisons using the Kolmogorov-Smirnov test were made difficult by the fact that the variances of the compared burdens differed considerably. Thus in no case was it possible to find a factor to superimpose the two cumulative probability curves as was done for vegetative organisms. This is attributed to the use of a greater number of intervals in the spore simulation; the more accurate representation of the variance by the larger number of intervals disclosed a difference that had been lost in the 5-interval simulation.

Using the graphic method, it is clear that the Phase V mated surface burden still exceeds that for Phase VI by a factor of about 2. However, the exterior burdens differ by little, and the Phase VI burden is slightly greater in this case. The effects of the cleaning operation appear to be lessened in the spore simulation due to the smaller initial burdens and fallout rates for spores.

Two estimates of the total spore burden were calculated by JPL as described in Reference 1. Data from the swab-rinse assays produced an estimate of 6000 aerobic spores, whereas the environmental settling strip data gave an estimate of 260,000 spores. These estimates correspond to the 0.03 and 0.97 (respectively) probability points on the cumulative probability curve of the Phase VI burden prediction. The most likely interval (probability = 0.191) from the Phase VI prediction was from 33,000 to 50,000 spores, approximately midway between the two JPL estimates (on a logarithmic scale).

IV RECOMMENDATIONS FOR PROGRAM CONTINUATION

The microbial burden prediction for the MV 67 spacecraft as computed in Phase VI of this contract is not inconsistent with the burden estimates calculated by JPL, but better agreement might be desired. Since the present study compared only the final burden predictions, many additional comparisons remain to be made with the assay data taken during the six months the MV 67 was being assembled and tested. Thus the accuracy of the burden predictions could be checked (and improved as necessary) by comparing predicted burdens with the weekly assays and adjusting the input parameters to the burden prediction model to obtain the best agreement. The result would be a burden prediction model of sufficient dependability to permit a considerable reduction in microbiological assay work during the assembly and test of space hardware. Extrapolation of the burden prediction from the time of the last possible assay to the time of launch could also be done with confidence.

Certain changes are also indicated to enable the burden prediction model to be more useful as a tool for maintaining day-to-day burden estimates.

Six tasks have been identified to accomplish the above work:

1) Development of a statistically valid method to compare the burden estimates of the model with the actual samples;

2) Development of a computer program to determine the parameter values that give the best correlation between predictions and assays;

3) Determination of the stability of the burden accumulation process to define the limits of divergence from the true burden after assays are no longer taken;

4) Development of a general technique to calculate tolerance limits for the microbial burden from:

   a) the output of the burden prediction model,
   b) the degree of correlation between predictions and assays,
   c) the divergence limits determined in (3);

5) Determination of an efficient sampling strategy; i.e., when and how much sampling to do;

6) Improvement of the burden prediction model to permit:

   a) Daily restarts with minimum wasted time,
   b) Alteration of data on tape,
   c) Faster running,
   d) Print-out options to reduce printing time.

V ASSUMPTIONS

1) All applicable assumptions listed in Table 10 of Volume I (Final Report for Phases I-III) also apply to the work in Phases IV-VI;

2) The distinction between top and other exterior surfaces was assumed unimportant in the MV67 due to frequent reorientation of the spacecraft;

3) No occluded surfaces were generated during the simulations, and it was assumed that none were initially present;

4) Personnel working near the spacecraft ("People in Area" entries in Reference 3) were assumed to be in the range of 0 to 5 ft from the hardware.

5) Activities in the Phase V simulation (planned sequence) were assumed to be performed sequentially;

6) A 40-hour work week was simulated in Phase V by inserting "Spacecraft secured in tent" at the end of every 8 hrs and on week-ends;

7) Initial burdens for all parts in Phases V and VI were assumed to correspond to the High Bay environment plateau burden;

8) Operations were assumed for each subtask in Phases V and VI based on the nature of the subtask;

9) In Phase VI, the Daily Activity Reports (References 2 and 3) were assumed complete; no additional activities were inserted to alter the total time for the simulated sequence;

10) The histogram derived for the average lifetime, v, was assumed applicable to all environments and for spores as well as vegetative organisms. The average lifetime for mated surfaces was arbitrarily increased by a factor of 10.

11) The environment "under shroud with N_2 purge" was assumed to be the same as the laminar flow tent;

12) It was assumed that surface retention of organisms does not depend on the surface material;

VI COMPUTER PROGRAM CHANGES

During Phases IV through VI three changes were made to the computer program developed in Phase III:

1) Inclusion of the number of men and the omission of the distance factor;
2) Adjustment of burden histograms to have specified probability levels;
3) Correction of the mean value after histogram manipulations.

This chapter describes the changes made in the computer program; the reasons for these changes were discussed in Chapter II.

To permit input of the number of men in the area, one card was replaced in subroutine MBS:

```
original card      Q  =  AQ*EXP(-AED(IE)*APD)
replaced with      Q  =  AQ*AED(IE).
```

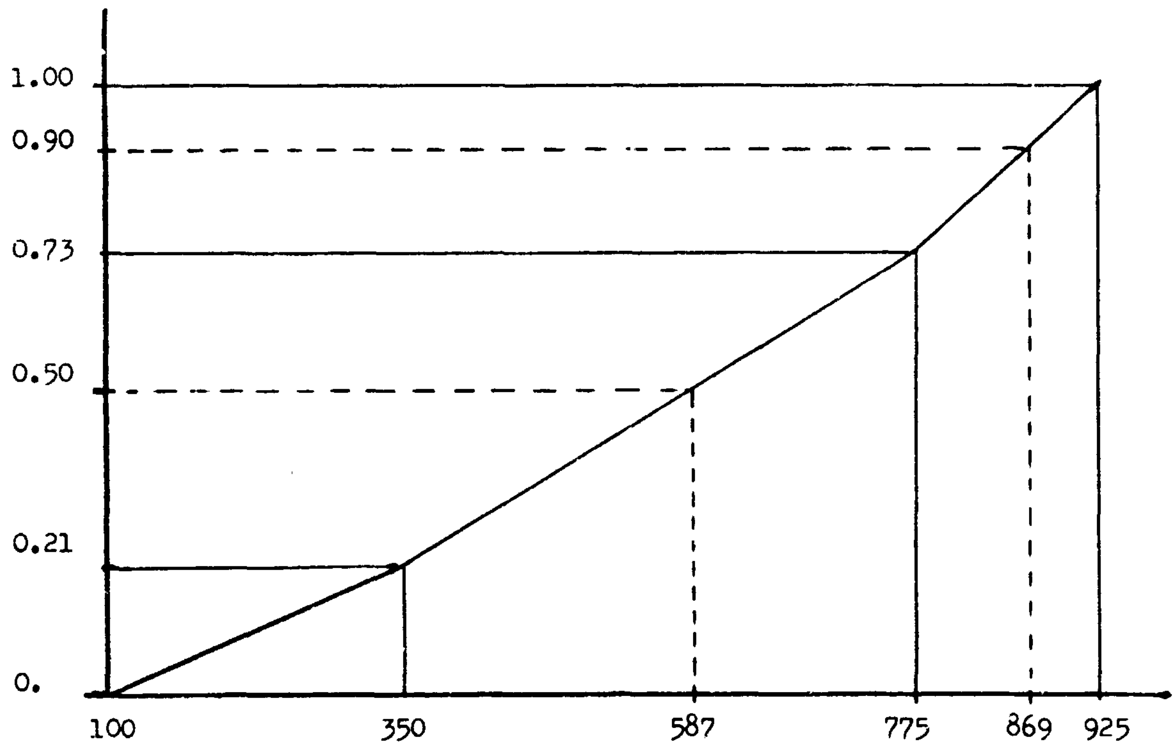
The parameter APD was not used in the Phase V and VI simulations.

To eliminate the tendency for the probability levels of burden histograms to shift, the computer program was changed to accept a set of prescribed probability levels and to find the corresponding burden ranges. To use this feature, it is necessary to input an additional histogram having the prescribed probability values (the card for the abscissae or x-values may be left blank) and inputting the index of this histogram as the entry I5 on any (one) control card. In succeeding tasks a linear interpolation is used to find the burden in the specified probability intervals each time the burden is updated.

For example, suppose the unadjusted burden histogram is:

	.21	.52	.27
100	350	775	925.

If the desired probabilities are 0.5, 0.4, and 0.1, the program constructs a cumulative distribution and interpolates as shown in the following diagram:



The resulting histogram is:

	.5	.4	.1
100	587	869	925.

The section added to subroutine HCS to accomplish this change is listed in Table 13.

To maintain the burden mean value, a parallel calculation of mean values is made during the histogram manipulations for fallout contamination. After the final burden for fallout has been calculated, its mean is adjusted to have the proper value. The section of subroutine MBS that was modified to accomplish this is listed in Table 14.

Table 14 Modification to Subroutine MBS

```
C     FALLOUT CONTAMINATION-
      CALL HMS(IQ,Q,I5)
      CALL HCS(I5,I6,I5,0,1)
C     I5 INDICATES THE TOTAL FALLOUT SOURCE CONCENTRATION (C+Q)
      AAT(IP)=DR(IT,1)
      DO 270 J=1,4
      IB=IAB(IP,J)
      F=AEF(IE,J)*AAG(IP)
      WRITE(11)IB,F
      IF(IB.LE.0)GO TO 270
      IF(F.LE.0.)GO TO 270
      V=AET(IE)*AES(J)
      VFG=V*F
      A=DR(IB,1)
      IF(A.LE.0.)GO TO 270
      AVR=A*VFG*(AEC(IE)+Q)
C     II IS THE DISTRIBUTION FOR V
      CALL HCS(15,II,I4,0,3)
C     I4 IS THE DISTRIBUTION FOR V*R
      CALL HCS(I7,II,I2,0,4)
C     I2 IS THE DISTRIBUTION FOR T/V
      M=NX(I2)
      NX(I3)=M
      DO 265 JJ=1,M
      DR(I3,JJ)=DR(I2,JJ)
      XR(I2,JJ)=EXP(-XR(I2,JJ))
  265 XR(I3,JJ)=1.-XR(I2,JJ)
C     I2 IS THE DISTRIBUTION FOR EXP(-T/V)
C     I3 IS THE DISTRIBUTION FOR 1-EXP(-T/V)
      CALL HCS(I4,I3,I4,0,3)
      CALL MVS(IB)
      EEE=EXP(-AKT/V)
      BBB=DR(IB,1)*EEE+AVR*(1.-EEE)
      CALL HCS(IB,I2,I2,0,3)
      CALL HCS(I2,I4,IB,IB,1)
      CALL MVS(IB)
      F=BBB/DR(IB,1)
      CALL HMS(IB,F,IB)
      DR(IB,1)=A
      MM=NX(IB)
      WRITE(11)IB,MM,(DR(IB,JJ),XR(IB,JJ),JJ=1,MM)
      WRITE(6,30)IP,J,IB,DR(IB,1)
      CALL HWS(IB)
  270 CONTINUE
```

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