MARINER MARS 1971

POST-LAUNCH ANALYSIS

OF COMPLIANCE WITH PLANETARY QUARANTINE

REQUIREMENTS

August 16, 1971

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SUMMARY

The Mariner Mars 1971 Project has updated the analysis for the probability, P_c, of contaminating Mars with viable terrestrial microorganisms. The updated analysis includes the revisions warranted by encapsulation microbiological assays, launch and early post-launch events. The probability of contamination results are as follows:

	Spacecraft	Pre-Launch Estimate	Post-Launch Estimate	Allocation
P_c Mission A	71-1	2.79×10^{-5}	nil*	7.1×10^{-5}
P_c Modified Mission A	71-2	$< 7.1 \times 10^{-5}$	1.57×10^{-5}	7.1×10^{-5}
P_c Mission B	-	6.77×10^{-5}	-	7.1×10^{-5}

The updated analysis indicates that with the modified Mission A strategy, including aiming point biasing and orbit periapsis altitude selection, the planetary quarantine constraints for the Mariner Mars 1971 Mission are being satisfied.

* Launch vehicle failure, spacecraft injection not achieved.

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SECTION I

INTRODUCTION

A. Purpose

This document provides justification to the NASA Planetary Quarantine Officer that the Mariner Mars (MM'71) Mission is complying with the COSPAR planetary quarantine recommendations.

B. Scope

The document is consistent with and responsive to the NASA document NHB 8020.12, Planetary Quarantine Provisions for Unmanned Planetary Missions and the MM'71 Planetary Quarantine Plan. The updated analysis includes revisions warranted by the encapsulation microbiological assays, launch and early post-launch events through July, 1971.

A supplement to this report shall be published in March, 1972, which will update the analysis for subsequent post-launch events, including orbit insertion and orbital operations.

C. Applicable Documents

The following Mariner Mars 1971 documents form a part of the report:

PD 610-18 Part I Rev A	Planetary Quarantine Plan
PD 610-18 Part II	Pre-launch Analysis of Probability of Planetary Contamination
PD 610-49	Targeting Specification
610-163 Chg 1	Spacecraft M71-2 Flight Configuration, Idiosyncracies, and Related Data

SECTION II

MISSION STATUS

The Mariner 71-1 spacecraft, designated as Mariner 8, was launched on May 8, 1971. Due to a hardware malfunction in the Centaur guidance system, the vehicle failed to achieve injection; the vehicle reentered the atmosphere and was destroyed. While the a'priori probability of contamination for Mariner 8, designated as the Mission A spacecraft, is the estimate published in PD 610-18, Part II, the a'posteriori estimate is essentially zero. With the failure of Mariner 8, a single spacecraft mission orbit was recommended by the Science Experimenter Team to try to acquire maximum scientific return with the remaining Mariner 9 spacecraft. Table 2.1 shows the selected single mission parameters consistent with the actual launch date.

On May 30, 1971, Mariner 9 was launched. In accord with PD 610-18, Part II, the launch vehicle was targeted to aim at a biased aim point with a B-vector of 43,539 km, as given in the Targeting Specification, PD 610-49. Following injection, spacecraft separation, solar panel deployment, medium gain antenna plug ejection, and the Centaur deflection maneuver were performed successfully. Orbit determination estimates indicate that the Centaur will pass approximately 493,100 km above the surface of Mars with a negligible probability of impact.

Pre-maneuver orbit determination results indicated that the actual post-separation aim point of the spacecraft had a B-vector of 32,954 km or would have passed 25,710 km from the surface of Mars. Accordingly, it has been predicted that the antenna plug will pass 22,430 km from the surface with a negligible probability of impact.

Five days after launch, the first midcourse maneuver was performed to move the spacecraft aim point to the desired for the single mission. This corresponded to an aim point with a B-vector of 8,195 km. The resulting maneuver required 6.73 m/sec and had an a'priori probability of impact of 1.5×10^{-10}.

Post-maneuver orbit determination to date shows that the spacecraft has a B-vector of 8,270 km with a negligible probability of impact. This B-vector would correspond to a close approach altitude of 1,732 km if no other maneuvers were performed. These results indicate that the present trajectories clearly satisfy the planetary quarantine requirements. A detailed summary of these trajectory and associated probability of impact results are given in Table 2.2.

The microbial burden estimates at the time of encapsulation for Mission 8 and 9 were 1.3×10^5 and 3.1×10^4, respectively (Appendix A).

TABLE 2.1

SINGLE MISSION PARAMETERS

Launch Date, LD	May 30, 1971
Arrival Date, AD	November 14, 1971
Heliocentric Phase	
Flight time, days	168
Radius to Mars at encounter, Mkm	211
Hyperbolic excess speed, V_∞, km/sec	3.23
Areocentric Phase	
Semi-major axis, a, km	12634
Eccentricity, e	0.6285
Inclination, i, deg	65
Longitude of ascending node, Ω, deg	42.20
Argument of periapsis, ω, deg.	334.24
Epoch	11/19/71, $03^h04^m00^s$
Periapsis altitude, h_p, km	1300
Apoapsis altitude, h_a, km	17181
Period, P, hr	11.98

Table 2.2

Trajectory Characteristics Summary

Parameter	Mariner 9
1. Targeted Biased Injection Aim Point	
B-vector, km	43.54×10^3
Orientation, Θ, deg	35.2
Close Approach Altitude, HCA, km	36.23×10^3
2. Actual Post Injection Aim Points	
a. Spacecraft Post-Separation	
B-vector, km	32.95×10^3
Θ, deg	37.0
HCA, km	25.71×10^3
b. Medium Gain Antenna Plug	
B-vector, km	29.65×10^3
Θ, deg	29.0
HCA, km	22.43×10^3
Probability of impact	nil
c. Centaur	
B-vector	50.06×10^4
Θ, deg	32.7
HCA, km	49.31×10^4
Probability of impact	nil
3. Trajectory Correction Maneuver	
a. Targeted Final Desired Aim Point	
B-vector, km	8195
Θ, deg	47.7
HCA, km	1667
b. Commanded Maneuver	
ΔV, m/sec	6.731
a'priori probability of impact	1.5×10^{-10}
4. Post-Maneuver Estimates	(Maneuver + 26 days)
B-vector, km	8270
Θ, deg	47.0
HCA, km	1732
Probability of impact	nil

SECTION III

PROBABILITY OF CONTAMINATION ANALYSIS

A. MISSION PROBABILITY OF CONTAMINATION

As given in III.B.1 of PD 610-18 Part I, the Mariner Mars 1971 Project is using the following basic analytical expression for computing the probability of contaminating Mars for this opportunity:

$$P_C = P_C(A) + P_C(NF) + P_C(C) + \sum_i P_C(EE_i)_{LV} + P_C(SC) + \sum_j P_C(EE_j)_{SC} \qquad (1)$$

where

P_C is the probability of contaminating Mars with one or more viable organisms.

$P_C(A)$, $P_C(NF)$, $P_C(C)$, $P_C(SC)$ are the probabilities of contaminating Mars from the large impactable sources including the Atlas, nose fairing, Centaur, and spacecraft.

$P_C(EE_i)_{LV}$, $P_C(EE_j)_{SC}$ are the probabilities of contaminating Mars with one or more viable organisms ejected from the ith (jth) ejecta-efflux source from the launch vehicle and spacecraft respectively.

In accordance with PD 610-18, Part I, IV.4, the Mariner Mars 1971 Project has calculated revised probabilities of contamination for each term in the right hand member of expression (1) based on updated estimates. The postlaunch estimates are compared to the prelaunch estimates and allocations in Table 3.1. More detail for the spacecraft estimates is given in Figure 3.1.

B. CONTAMINATION SOURCES ANALYSIS

1. Large Impactable Sources

The new single mission, which is essentially a modified Mission A, does not change the analysis or probability of impact parameters published in the prelaunch analysis for the heliocentric phase.

The "Time Dependent Mars Atmospheric Model" adopted in PD 610-18, Part I, Rev. A, and the new single mission orbit do require, however, revised orbital lifetime and probability of impact results. Figure 3.2 shows the orbital lifetime of the spacecraft as a function of the initial periapsis altitude using the worst case atmospheric solar cycle parameters for a 17 year lifetime. The wiggles in the curve are produced by the time varying characteristics of the atmosphere model. That is to say, the lifetime curve becomes more flat at the lifetimes or times when the atmosphere density profile is most dense, and becomes more vertical when the density is least dense. From the figure, the absolute minimum periapsis altitude, H_p(min), for a 17 year lifetime is 620 km. Figure 3.3 shows the corresponding minimum target elliptical periapsis altitude constraints that satisfy the spacecraft 17 years lifetime and probability of impact requirements. The one sigma delivery dispersion in periapsis altitude of 45 km, for the Mars orbit insertion (MOI) maneuver, is somewhat smaller than that presented in the prelaunch analysis because the single mission insertion maneuver strategy is to always target for a 1300 km or higher periapsis altitude. This strategy results from the

Science Experimenter Team single mission orbit recommendations. Accordingly, using the current value of $P_{\overline{T}/oi} = 2 \times 10^{-2}$, the probability that a required periapsis altitude trim cannot be executed successfully given MOI, the minimum target periapsis altitude at MOI is 777 km. Since this altitude constraint is well below the 1300 km target altitude, the mission easily satisfies the constraint with a very small probability of impact. A summary of the significant parameters and the resulting probability of spacecraft impact $P_I(SC)$, using eq. (2) of Appendix B-2, MD 610-18, Part II, follows:

H_p(min)	620 km
MOI Periapsis Dispersion Error	45 km (1σ)
Periapsis Trim Error	2 km (1σ)
Trim ΔV Allocation	99 m/s
$P_{\overline{T}/oi}$	2×10^{-2}
P_{oi}	1.

Which results in

$P_I(SC)$	< 15.1 σ or nil

As can be seen in Figure 3.2, the predicted orbital lifetime is very much greater than 50 years at the desired 1300 km periapsis altitude. If later in the mission the periapsis altitude is modified, the periapsis altitude will be chosen such that the probability of impact constraint is satisfied with the spacecraft lifetime greater than 17 years or through January 1, 1989, the Mars period of biological exploration.

Table 3-1

Mariner Mars 1971 Mission Probability

of Contamination Results

Probability	Prelaunch Estimate	Postlaunch Estimate**	Allocation
P_C Mission A	2.79×10^{-5}	1.57×10^{-5}	7.1×10^{-5}
Mission B	6.77×10^{-5}		7.1×10^{-5}
$P_C(A)$*	nil	nil	nil
$P_C(NF)$*	nil	nil	nil
$P_C(C)$ Mission A	0.98×10^{-8}	nil	26×10^{-8}
Mission B	1.47×10^{-8}		26×10^{-8}
$\sum_i P_C(EE_i)_{LV}$ Mission A	2.6×10^{-8}	1.4×10^{-8}	4×10^{-8}
Mission B	1.7×10^{-8}		
$P_C(SC)$ Mission A	25.8×10^{-6}	1.0×10^{-6}	31.7×10^{-6}
Mission B	30.8×10^{-6}		
$\sum_j P_C(EE_j)_{SC}$ Mission A	2.07×10^{-6}	14.7×10^{-6}	39×10^{-6}
	36.9×10^{-6}		

* Atlas and nose fairing do not achieve escape velocity.

** Modified Mission A, i.e., Mariner 9.

KEY: A: **ALLOCATION**
E: **POSTLAUNCH ESTIMATE**

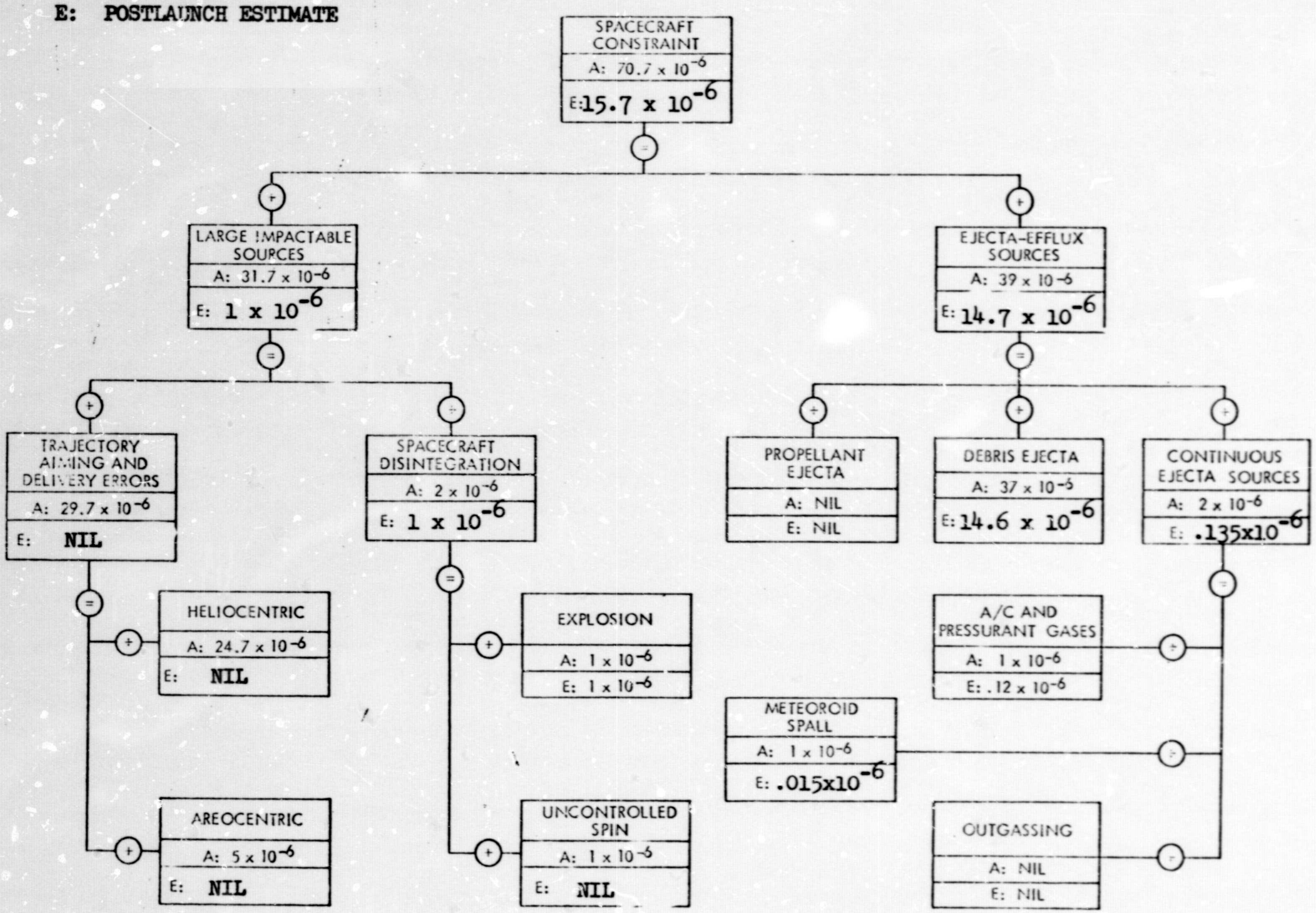


Figure 3.1 Spacecraft Planetary Quarantine Model

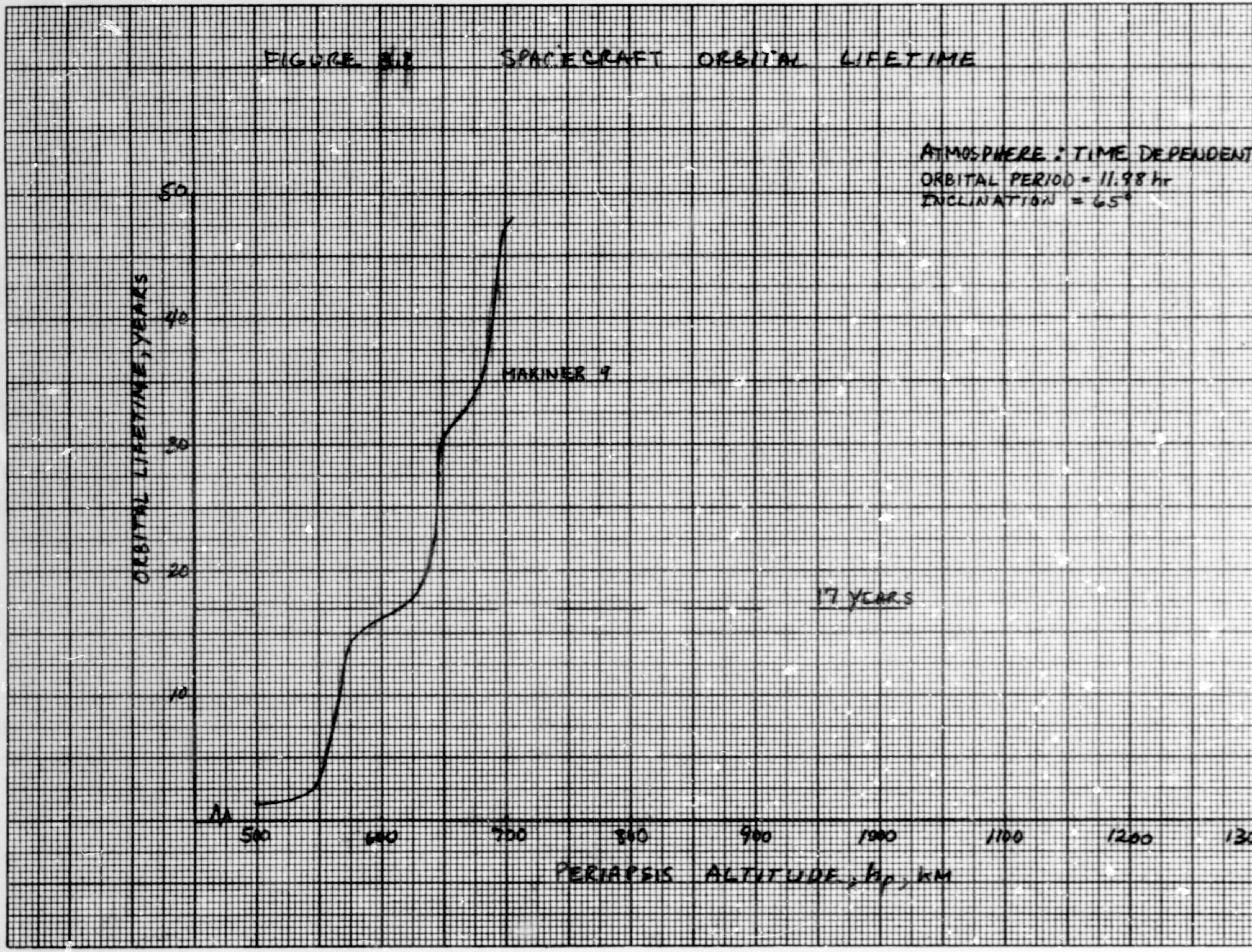


FIGURE 3.2 SPACECRAFT ORBITAL LIFETIME
ATMOSPHERE : TIME DEPENDENT
ORBITAL PERIOD = 11.98 hr
INCLINATION = 65°
MARINER 9
17 YEARS
ORBITAL LIFETIME, YEARS
50
40
30
20
10
500
600
700
800
900
1000
1100
1200
1300
PERIAPSIS ALTITUDE, hp, km

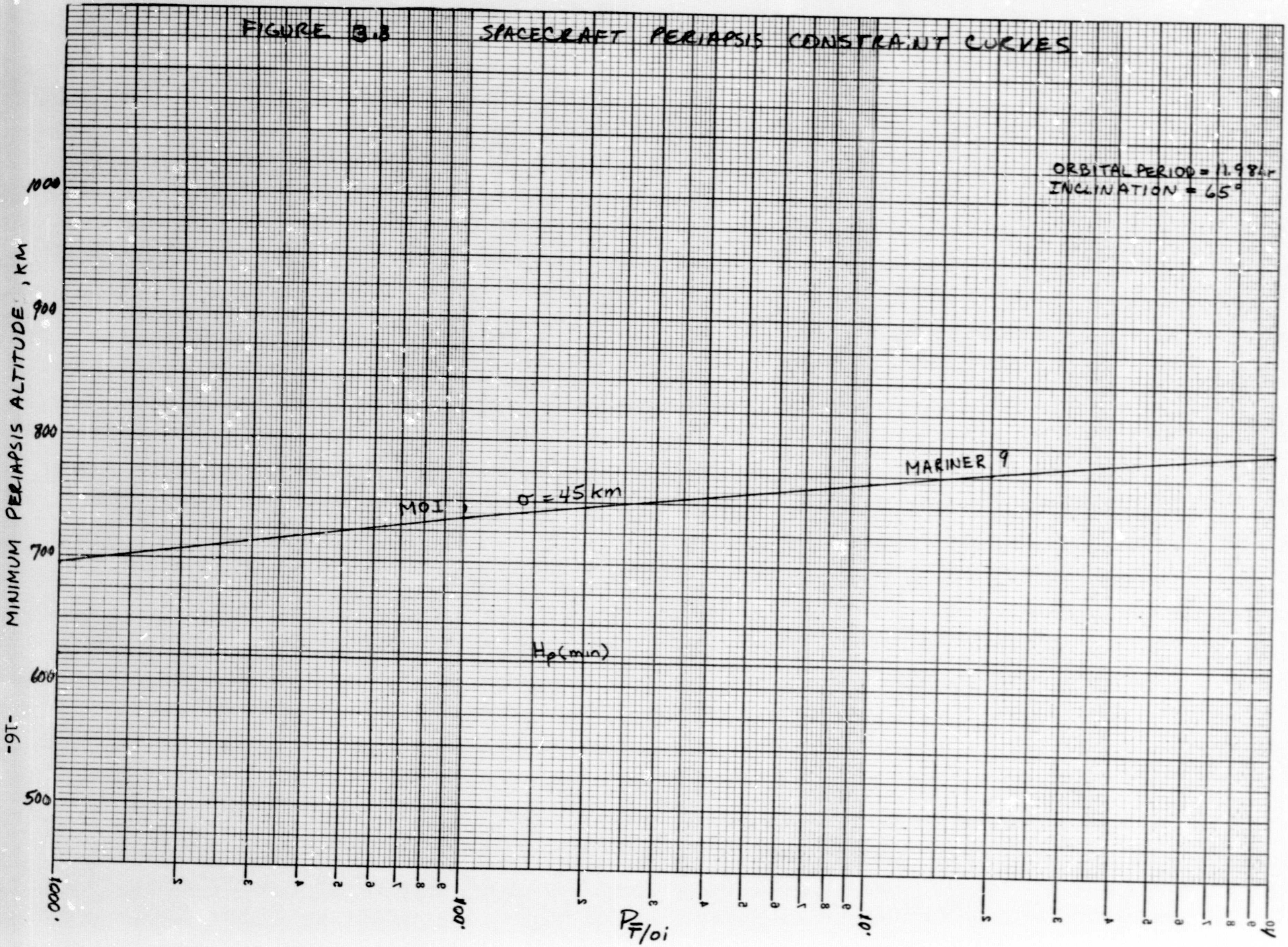


FIGURE 3.8 SPACECRAFT PERIAPSIS CONSTRAINT CURVES

2. Ejecta Efflux Sources

The probability of contamination for the ejecta efflux sources have been revised by evaluating the appropriate equations from PD 610-18, Part I and Part II. Since the Centaur ejecta efflux probabilities are dominated by the debris ejecta and the deflection maneuver was successfully performed, the revised ejecta probability estimate is 1.4×10^{-8}.

Changes in the spacecraft probability of contamination ejecta efflux estimates for different missions are reflected through the $P_E \times P_T$ probability term. Pre-launch analysis studies have shown that the $P_E \times P_T$ estimates for A/C and pressurant gases during the heliocentric phase are insensitive to changes in the mission (Table C-2.1, PD 610-18, Part II). Debris ejecta estimates are, however, sensitive to changes in mission parameters. Meteoroid spall estimates vary slightly with such changes. Figures 3.4 and 3.5 show the $P_E \times P_T$ estimates for these sources during the heliocentric phase for the spacecraft targeted to the single mission final desired aim point. From the figures, the $P_E \times P_T$ estimates are 3.72×10^{-1} and 4.7×10^{-6} for debris ejecta and meteoroid spall, respectively. For all ejecta - efflux sources, the estimates are independent of mission parameters in the areocentric phase where $P_E \times P_T = 1$.

The revised bioburden estimates used in the analysis are summarized in Table III.1.

TABLE 3.2

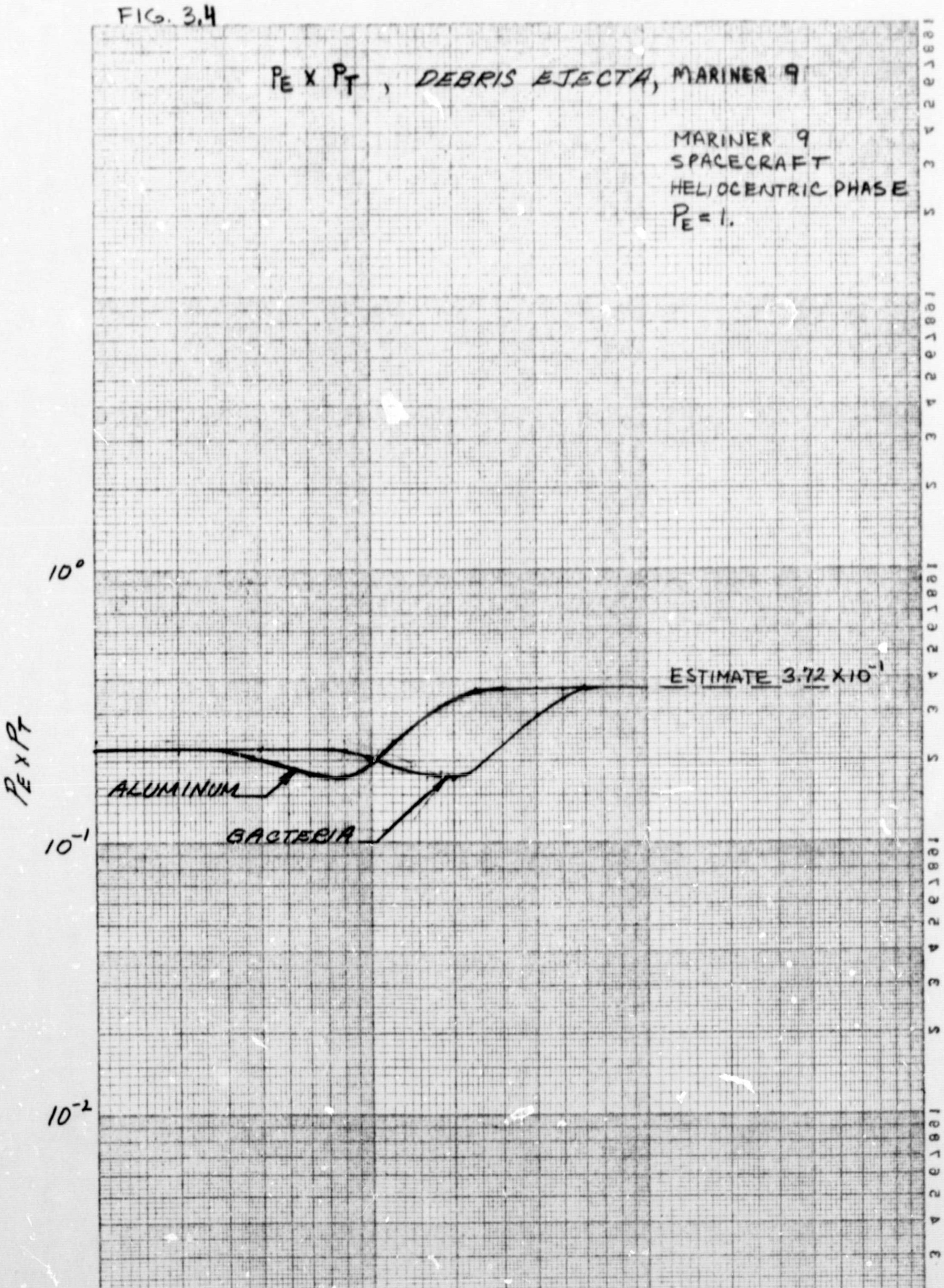
SPACECRAFT BIOBURDEN PARAMETERS*

Ejecta Efflux Source	Heliocentric Estimate	Areocentric Estimate
Debris Ejecta, including loose particles	3.1×10^4	3.1×10^3
Exposed surface for Meteoroid Spall	3.1×10^4	3.1×10^3
Attitude Control and Propulsion Pressurant Gas	1×10^3	1×10^2

*Total Count

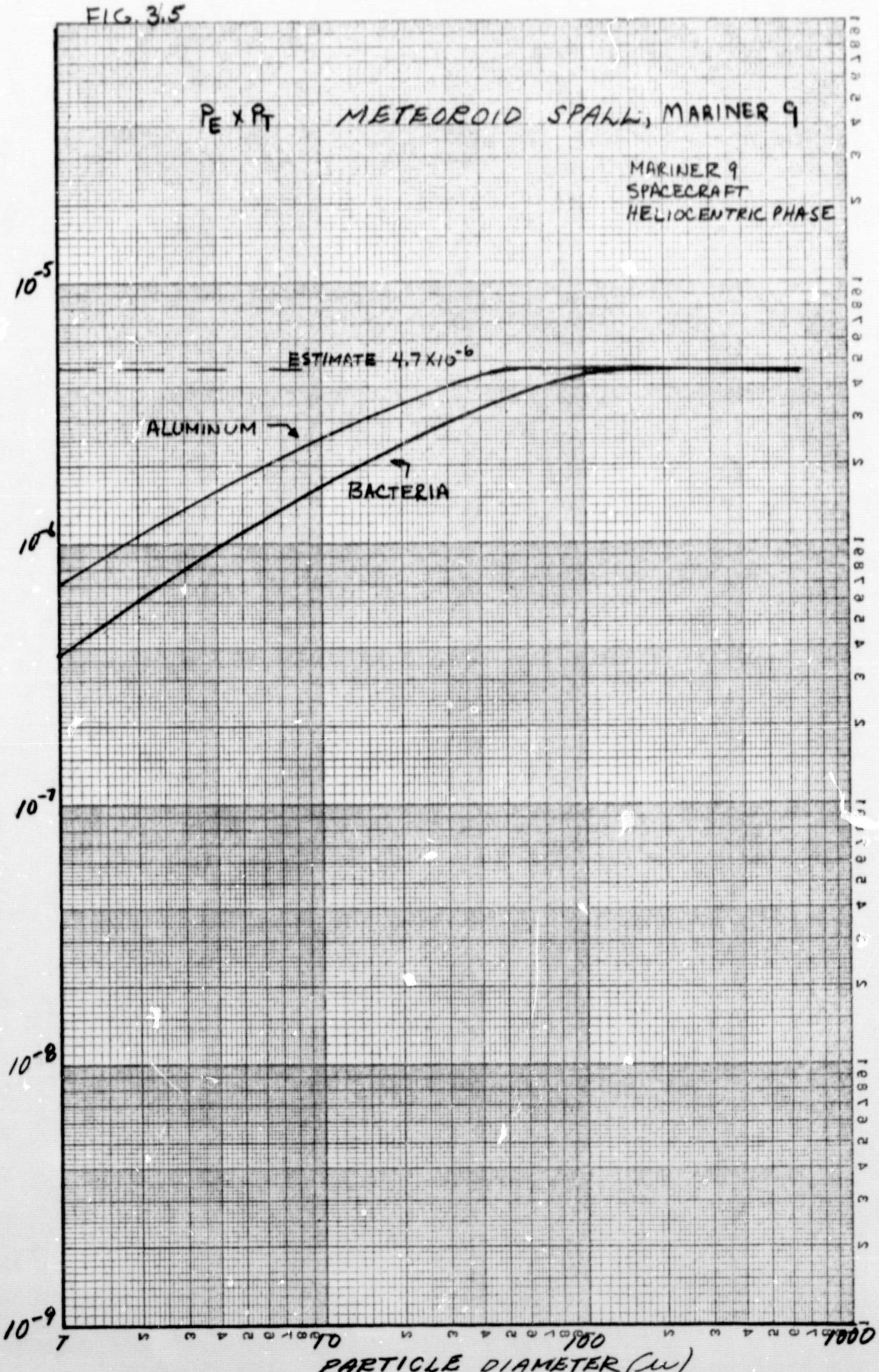
The revised results of the ejecta efflux analysis are summarized in Table 3-1 and Figure 3.1.

FIG. 3.4



$P_E \times P_T$, DEBRIS EJECTA, MARINER 9
MARINER 9
SPACECRAFT
HELIOCENTRIC PHASE
$P_E = 1.$
ESTIMATE 3.72×10^{-1}
ALUMINUM
BACTERIA
10^0
10^{-1}
10^{-2}
10^{-3}
$P_E \times P_T$
1
10
100
PARTICLE DIAMETER (μ)

FIG. 3.5



$P_E \times P_T$ METEOROID SPALL, MARINER 9
MARINER 9
SPACECRAFT
HELIOCENTRIC PHASE
ESTIMATE 4.7×10^{-6}
ALUMINUM
BACTERIA
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
$P_E \times P_T$
1
10
100
1000
PARTICLE DIAMETER (μ)

APPENDIX A

RESULTS OF MARINER MARS 1971 ENCAPSULATION MICROBIOLOGICAL ASSAYS

The results of the encapsulation microbiological assays for the flight spacecraft are given in this appendix. The burden was calculated in accordance with the method given in Appendix A of PO 610-18, Part III, "Microbiological Assay and Monitoring Plan."

The results of the encapsulation microbiological sampling for the Flight 1 spacecraft are given in Table A.1.

TABLE A.1

FLIGHT 1 SPACECRAFT

ENCAPSULATION MICROBIAL BURDEN

EXPOSED SURFACES

Zone	Estimate of Vegetative Organisms*	Estimate of Spore Organisms	Date Zone Sampled
Structure	[illegible]	0	5/2/71
Solar Panels			
Front	18,711	0	4/19/71
Rear	88,084	2,318	5/2/71
Thermal Blankets			
Propulsion Module	6,247	0	5/2/71
Lower Thermal	2,344	0	5/1/71
Scan Platform	2,208	0	5/1/71
Rocket Engine	0	0	5/2/71
High Gain Antenna	12,340	9,990	5/2/71
Spacecraft Total	129,924	12,308	

* Total Count

The results for the microbiological sampling for the Flight 2 spacecraft prior to the removal of the IRIS for rework are given in Table A.2.

TABLE A.2

FLIGHT 2 SPACECRAFT

ENCAPSULATION (ESF ASSAY 1) MICROBIAL BURDEN

EXPOSED SURFACES

Zone	Estimate of Vegetative Organisms	Estimate of Spore Organisms	Date Zone Sampled
Structure	807	0	4/26/71
Solar Panels			
Front	7,970	0	4/21/71
Rear	39,406	1,159	4/26/71
Thermal Blankets			
Propulsion Module	0	0	4/26/71
Lower Thermal	0	0	4/19/71
Scan Platform	0	0	4/19/71
Rocket Engine	0	0	4/26/71
High Gain Antenna	1,266	0	4/26/71
Spacecraft Total	49,449	1,159	

* Total Count

The results of the reconfirmation encapsulation sampling for the Flight 2 spacecraft are given in Table A.3.

TABLE A.3

FLIGHT 2 SPACECRAFT

ENCAPSULATION (ESF ASSAY 2) MICROBIAL BURDEN

EXPOSED SURFACES

Zone	Estimate of Vegetative Organisms*	Estimate of Spore Organisms	Date Zone Sampled
Structure	0	0	5/10/71
Solar Panels			
Front	7,970	0	4/21/71
Rear	22,021	1,159	5/10/71
Thermal Blankets			
Propulsion Module	781	0	5/10/71
Lower Thermal	0	0	5/6/71
Scan Platform	0	0	5/6/71
Rocket Engine	0	0	5/10/71
High Gain Antenna	0	0	5/10/71
Spacecraft Total	30,772	1,159	

* Total Count

All biological controls were negative indicating no microbiological contamination was introduced during the assaying procedure.

The reconfirmation bio-assay indicated that the IRIS removal and re-installation activities did not result in an increase in the burden on the spacecraft. This was attributed to the fact that the spacecraft was kept in a class 100 laminar flow tent and personnel access to the spacecraft was very restricted.

APPENDIX B

PLANETARY QUARANTINE

CERTIFICATIONS

COPY

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

REPLY TO ATTN OF: SL

May 5, 1971

MEMORANDUM

TO: S/Associate Administrator for Space Science and Applications

FROM: SL/Planetary Quarantine Officer

SUBJECT: Planetary Quarantine Certification of Mariner-Mars 1971 Mission A

This office has reviewed the Mariner-Mars 1971 prelaunch analysis of the probability of contaminating Mars with viable terrestrial microorganisms and we are monitoring, up to the time of launch, the microbial load on each mission.

We find that the proposed trajectory, during the heliocentric and areocentric phases of the Mission, and the planned microbial contamination control during the prelaunch and launch operations will result in a probability of 7.1×10^{-5} or less, of accidentally contaminating the planet Mars with terrestrial organisms by each of the orbiting flight missions. This probability of contaminating Mars is within the constraints of NASA policy.

It is recommended that the Mariner-Mars 1971 Mission A be certified to the Administrator as being in compliance with the National Aeronautics and Space Administration policy for planetary quarantine as stated in NPD 8020.10.

We will submit a recommendation for Mariner-Mars Mission B on May 11, 1971 if the level of the microbial load on that mission can be confirmed as being within limits at the time of encapsulation.

/s/
Lawrence B. Hall

CONCURRENCE: /s/ Robert S. Kraemer — April 30, 1971
SL/R. S. Kraemer, Director — Date:

C O P Y

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

REPLY TO ATTN OF: SL

May 6, 1971

MEMORANDUM

TO: A/Administrator

FROM: S/Associate Administrator for Space Science and Applications

SUBJECT: Planetary Quarantine Certification of Mariner-Mars 1971 Mission A

This is to certify that the Mariner-Mars 1971 Mission A complies with National Aeronautics and Space Administration planetary quarantine policy as stated in NPD 8020.10.

Certification is based on a memorandum from the Planetary Quarantine Officer dated May 5, 1971, stating that the trajectory plans, midcourse and orbital maneuver capability, and microbial load of the spacecraft provide a probability of contamination in compliance with established National Aeronautics and Space Administration requirements.

/s/
John E. Naugle

cc: SL/Director
SL/Planetary Quarantine Office
JPL/MM '71 Project Manager

/s/
R. S. Kraemer, Director
Planetary Programs, OSSA

5-5-71
Date:

C O P Y

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

REPLY TO
ATTN OF: SL

May 25, 1971

MEMORANDUM

TO: S/Associate Administrator for
Space Science and Applications

FROM: SL/Planetary Quarantine Officer

SUBJECT: Planetary Quarantine Certification of
Mariner I for Launch

We have found that the microbial load on Mariner I and other factors are within the limits required to provide a probability of contaminating Mars of 7.1×10^{-5} or less if flown as Mission A or B or a combination of the two.

It is therefore recommended that the Mariner I be certified to the Administrator as being in compliance with the National Aeronautics and Space Administration policy for planetary quarantine as stated in NPD 8020.10.

/s/
Lawrence B. Hall

CONCURRENCE: /s/ 5/21/71
SL/R. S. Kraemer, Director Date:
Planetary Programs, OSSA

COPY

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546

REPLY TO ATTN OF: SL

May 25, 1971

MEMORANDUM

TO: A/Administrator

FROM: S/Associate Administrator for Space Science and Applications

SUBJECT: Planetary Quarantine Certification of Mariner I for Launch

This is to certify that the Mariner I complies with NASA planetary quarantine policy as stated in NPD 8020.10.

Certification is based on a memorandum from the Planetary Quarantine Officer dated May 25, 1971, stating that the trajectory plans, midcourse and orbital maneuver capability, and microbial load on the spacecraft provide approbability of contamination of Mars in compliance with established National Aeronautics and Space Administration requirements.

/s/
John E. Naugle

CONCURRENCE: /s/ SL/Director   5/21/71 Date: