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FINAL REPORT

**POST VIKING PLANETARY PROTECTION
REQUIREMENTS STUDY
AUGUST 31, 1977**

(NASA-CR-155585) POST VIKING PLANETARY
PROTECTION REQUIREMENTS STUDY Final Report
(Exotech Research and Analysis, Inc.) 34 p
HC A03/MF A01 CSCI 22B

N78-16088

Unclas
G3/18 04196

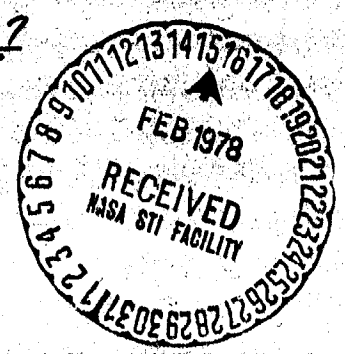
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4800 OAK GROVE DRIVE
PASADENA, CALIFORNIA 91103

UNDER CONTRACT: JPL 954807



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INTRODUCTION

The basic objective of this contract was to perform a study of post Viking Planetary Protection requirements applicable to future outbound Mars missions.

Considerable assistance was obtained from M. Christensen and G. Ervin in helping to scope and focus the study effort.

The specific focus of this study was to review; (a) past Planetary Quarantine requirements, (b) presently released Viking science data and, (c) current planning activity for a 1984 Mars mission in order to see what the implications of Planetary Protection (PP) activities might be for an '84 Mars mission.

The term Planetary Quarantine (PQ) has, in the past, not specifically included either Organic Contamination Control (OCC) or Biology Experiment contamination control. These two items were essentially under the direction of the Science experiment teams. The currently used term Planetary Protection, although similar to the old PQ term, is used in a somewhat broader sense. During this period of transition to a broader scope there is of necessity some ambiguity of terms. We have tried, therefore, in this report to explain what is, or is not, included in the various sections of the report. Where not specified, we use PQ when referring to the past and PP when referring to the future.

1.0 STUDY APPROACH

The approach chosen to accomplish the study objective is shown in Figure 1. The results of each task are discussed in the following sections of this report.

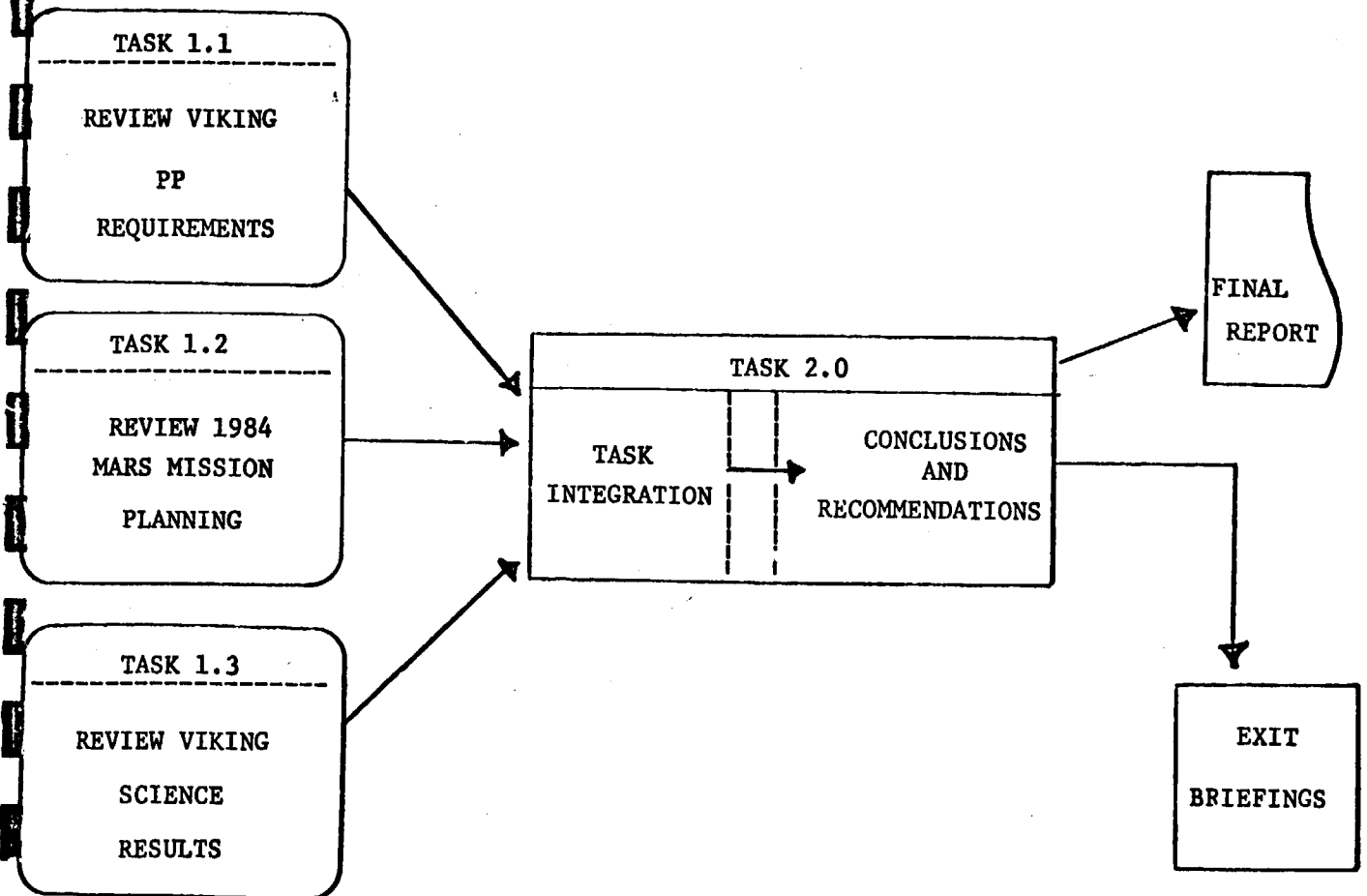


FIGURE 1
STUDY TASKS

1.1 Viking '75 Planetary Quarantine Requirements

The U. S. Planetary Quarantine activities have been extensively documented. This report starts at the point of the specific top level requirements on Viking and briefly describes the approaches the project chose to meet these requirements. The material presented in this section was derived from review of information contained in the NASA Headquarters Planetary Quarantine Document System (maintained by Exotech) and the author's personal experience on the Viking Project.

Organic Contamination Control

The presence of the GCMS experiment on Viking led the Molecular Analysis Team to require an extensive contamination control program. This effort, known as Organic Contamination Control, was not a part of the Planetary Quarantine activities and is not examined in this report. For purposes of background information the following summary of the highlights of the OCC effort is given:

- Established 1.0 ppm as the maximum allowable terrestrial contamination in any sample of Mars soil.
- Identified significant sources of organic contamination as condensation of volatile material due to outgassing of organic materials used in the spacecraft;

fallout of particulate material from the Lander to the Mars surface; surface films, materials and particulate matter within the GCMS instrument and engine exhaust contamination.

- Controlled contamination: by careful selection and control of all Lander materials, processes and fabrication; extensive multi-level cleaning and controlled storage of the Lander; special nanogram level cleaning of the GCMS instrument; and extensive analysis of engine exhaust contamination (Site Alteration Studies) and implementation of related control activities (use of "pure" descent engine fuel).

Biology Experiment Protection

The presence of the Biology experiment on Viking led the Biology Science Team to impose a requirement that the probability of contaminating the experiment be less than one chance in a million (i. e., $P_{cb} \leq 10^{-6}$; where P_{cb} is the probability of contaminating the Biology experiment). At one point early in the Viking program there was discussion relating to the possible reduction of the PQ parameter $P(g)$ to 10^{-9} . Extensive studies were performed by the project which showed that; from a PQ standpoint, the decontamination activities could be greatly reduced (i.e., dry heat sterilization of the Lander would not be necessary); from the standpoint of protecting the Biology Experiment, greatly increased

measures would have to be developed, tested and implemented to try to compensate for a non-heat-sterilized Lander; from an overall project standpoint, it was decided that sterilization of the Lander would still be implemented to protect the Biology experiment even if $P(g)$ was reduced. As it turned out $P(g)$ was never changed to 10^{-9} . The final implementation of PQ and Biology protection requirements included all the items discussed in the remainder of this section plus more stringent special heating of the Biology experiment at the component level and the implementation of special precautions to prevent recontamination prior to the overall Lander sterilization.

Data based on extensive studies using naturally occurring microbial populations revealed the presence in spacecraft microbial populations of a small number of very heat resistant organisms, so called "Hardy Organisms". These results were accounted for in the Biology protection activities as well as in the PQ activities although all of the formal documentation did not specifically address these unique spore populations.

Planetary Quarantine

National and international policies imposed PQ requirements on Viking. The prime top level requirement was: the probability of contaminating Mars by each Viking Spacecraft shall be less than one chance in ten thousand (i.e. $P(c) \leq 10^{-4}$). This basic allocation was sub-allocated by the project to the various portions of the mission. The U. S. PQ approach provides wide latitude for the individual projects to determine how they will meet the broad overall Planetary Quarantine requirements. Consequently,

extensive analyses, research and tradeoff studies were performed for many years by the project in arriving at the finally implemented approaches used to assure meeting project PQ requirements, as well as all other project requirements. A large data base exists for all portions of the PQ activities which were required to be documented by International agreements and by NASA Headquarters. Activity is currently being initiated to collect lower level documentation of project efforts involved in implementing the various PQ requirements so that the technology used will be available for future reference. No attempt is made in the current study to present the picture of Viking PQ activities in a quantitative manner, or even in a detailed qualitative manner. The work performed by the project was far too extensive to be covered in the current brief study and report. What is included is a qualitative overview of the PQ technology used by the Viking project to meet their requirements. This overview is presented in Table 1.1 and discussed in the following paragraphs.

The first major column in Table 1.1 essentially lists second level contamination sources identified in the project PQ analysis. Each of these sources had assigned to it a sub-allocation of the total probability of contamination allocation and hence had a numerical requirement to be met. The second column identifies the approach(es) implemented by the project to assure that the numerical PQ requirements were being met. The third and fourth columns respectively indicate the degree of dependence of the requirement/approach on the value of $P(g)$ and the requirement to not contaminate the Viking Biology experiment.

General Discussion of Table 1.1

The large impactable sources 1.1 through 1.6 are all capable of contaminating Mars if they impact. Since the microbial burdens on these hardware items are all large, the general approach used on Viking as well as on all prior U. S. Mars missions has been to conservatively assume that Mars would be contaminated if the hardware impacted and therefore to assure that it did not impact Mars. In other words, the probability of contamination given impact was assumed to be 1.0. This basically meant that $P(g)$ did not enter into these calculations. However, if $P(g)$ were to get smaller it would mean; (1) there would potentially be more allocation available to use for large impactable sources and (2) it might pay, depending on how small $P(g)$ gets, to actually consider the probability of contamination given impact rather than conservatively assume it to be 1.0.

Requirements No. 1.5 and 1.6, involving maintenance of orbital lifetime, are actually separate requirements in the NASA Headquarters parameter specification system. However, if $P(g)$ were to become small enough, this separate requirement would be subject to re-evaluation. The ability of any of the large impactables to contaminate the Viking Biology instrument is essentially negligible since a large impactable would not only have to impact Mars, but it would have to impact very close to a Lander.

A major portion of the work associated with meeting PQ and Biology Requirements was involved with development of reliable, dry heat sterilization hardware (See Lander sterilization, Requirement 2.1 Item (a)). This effort consisted of many activities including: careful attention to the selection and screening of electronic and mechanical parts; careful selection of materials; special efforts applied to the design, fabrication and test of components known from previous research to be heat sensitive, namely, batteries, gyroscopes, accelerometers and recorders; utilization of Mandatory Parts for general usage in circuit design; single production lot procurements of parts; electronic packaging design; control of solder, soldering and conformal coating thickness; Materials Testing to establish chemical and physical properties of non-metallic materials; and, extensive testing and review of the overall design/development process.

Item 2.1, b refers to the complex thermal aspects of the Lander, including the sterilization requirement. Early thermal analysis revealed that the Lander interior would heat very slowly during sterilization. This was due to the thermal insulation needed to maintain thermal control during the extremes of the Martian day/night cycle. A further thermal complication arises from the need to cool the RTG's during sterilization and thereafter until launch. A major problem which would result from slow interior heating of the Lander would be an unusually long heating time for the

faster heating components on the Lander. The project designed/ implemented an approach which minimized this problem by introducing hot nitrogen into the interior of the Lander during sterilization and by utilizing the RTG heating and coolant lines to provide an interior heat source during sterilization.

A second major thermal requirement arose from the necessity to be assured - - by only a few temperature measurements during actual sterilization - - that every component on the Lander was receiving its design temperature-time cycle. This was accomplished by extensive analysis and test at the component, subsystem and system level. The coldest point of each component was identified by analysis and test, and then about 500 thermocouple measurements were made on a Lander thermal model (TETM). This thermal test vehicle served many purposes, including checking out the sterilization approach, the Lander thermal characteristics, the ground support equipment compatibility with the RTG coolant/sporicide (a formaldehyde-isopropanol mixture) and effects of outgassing of moisture and oxygen on the specified sterilization environment (i.e., moisture 25% at 0°C and 760 mm Hg at the bioshield outlet).

Item 2.1, c involved the use of a computerized bookkeeping system to keep track of all components used in the several Viking vehicles. This was necessary to allow accurate estimation of the pre-, and post-sterilization bioload. The program included; several categories of bioburden (buried, mated and surface), component

areas and volumes, component ID's, the specific components used on each vehicle and the various materials and related bioburdens associated with repairs on components previously heat treated at the component level, component thermal parameters, and vehicle thermal parameters and zones. Utilization of this tool assisted the project in exercising complete and accurate control of the data needed for bioburden estimation.

Item 2.1 d, component heat treatment, is the first step in the project's two step sterilization approach. This step consisted of a component level heat cycle designed to reduce the buried bioburden so that the final sterilization cycle could be shorter. Subsequent recontamination of the component surfaces was, of course, accounted for and reduced to a satisfactorily lower bioburden level during the final sterilization of the entire Lander.

Item 2.1 e, multiple bioassays, consisted of a series of microbiological assays of Viking hardware. These assays were required for two major purposes; (a) to assure that the final sterilization process was designed to achieve the required bioburden reduction and, (b) to establish that the overall PQ contamination estimations were within the allowed allocations. Each microbial milestones consisted of approximately 250 samples. The sequential nature of the milestones permitted corrective actions to be implemented, if necessary, and provided the appropriate bioburden numbers for mated surfaces during fabrication. The milestones were:

<u>VEHICLE</u>	<u>MILESTONE</u>
Each Lander	1 - Denver, pre-environmental testing
Each Lander	2 - Denver, pre-ship
Each Lander	3 - KSC - Disassembly
Each Lander	4 - KSC - Reassembly
Each Lander	5 - KSC - Pre-Mate
Each Lander	6 - KSC - Pre-Encapsulation
Each Shroud	7 - KSC - Shroud Interior
Each Orbiter	1 - Pasadena, Post-environmental disassembly
Each Orbiter	2 - Pasadena, pre-ship
Each Orbiter	3 - KSC - Mechanical Prep and Pre ESF Transport
Each Orbiter	4 - KSC - Pre-Mate
Each Orbiter	5 - KSC - Pre-Encapsulation

Item 2.1 f, development of the sterilization facility, involved all activities related to the design, fabrication and test of the sterilization facilities, instrumentation and procedures. The Lander PTC vehicle was heat treated in an oven facility at Denver which served to check out the facility concepts as well as the flight type hardware. The facility served as a propellant loading facility for the Lander after the sterilization cycle. The procedures governing the actual sterilization cycle as well as the instrumentation (particularly relating to moisture and temperature measurements) were doubly important; the engineering organizations responsible for flight hardware did not want any extra heat, while the organizations responsible for PQ and Biology protection did not want the hardware overheated. Consequently, the margin for procedural or calibration errors was very small.

Item 2.1 g, The Biology Instrument Package, as previously explained, was not a part of the PQ requirement. The review and analysis of the various possible ways in which the Biology experiment could be contaminated as well as the estimated microbial populations (including Hardy organisms) which could survive the Lander sterilization cycle led the Biology Science team to implement a component dry heat cycle for the Biology experiment at a higher temperature than required for PQ, in addition to implementing special precautions to minimize re-contamination of the instrument prior to Lander sterilization. The major reason that the Biology instrument requirement was more stringent than the PQ requirement was that a P(g) of 1.0 was used inside the Biology Instrument and its immediate vicinity.

Item 2.1 h, was the actual sterilization of the two Viking Landers. This effort went essentially according to plan. One problem arose involving questions concerning AGE temperature measuring equipment. Special calibrations were performed which confirmed that the actual oven temperature was within specifications. The successful sterilization of the Viking Landers, and their subsequent successful operation on Mars, attest to the effort by all of the persons and organizations responsible for the above described design, development, fabrication and test activities.

Considerable effort went into assuring that the Landers were not re-contaminated after the sterilization cycle was complete. These efforts are described in Section 2.2 of Table 1.1. Items (c) and (d), insertion of the RTG coolant and the Lander propellants, indicate a weak and indirect relationship to the Biology Experiment requirement because recontamination due to either of these sources would, with a high probability, be confined within the respective plumbing and therefore would not materially interface with the Biology experiments. Item (e), the use of Class 100 air in the shroud, was of benefit to PQ and Biology, but the actual levying and enforcement of the requirement was not primarily for PQ or Biology Protection.

Item 3.0, ejecta-efflux, was treated very similarly to previous Mars missions and has been amply documented over the past decade.

TABLE 1.1
VIKING '75 PP MATRIX

REQUIREMENT		IMPLEMENTATION APPROACH	Degree of Dependence On	
NO.	NAME		P(g)	Biology Experiment Requirement
1.0	Large Impactables	Reduce probability of accidental impact on Mars	Indirect-only as it affects suballocation	Negligible (Neg)
1.1	Titan III Launch Vehicle & Nosefairing	Does not achieve earth escape velocity	Neg.	Neg.
1.2	Centaur	Aim point biasing and deflection maneuver	Indirect-only as it affects suballocation	Neg.
1.3	Bioshield Cap	Aim point biasing of s/c prior to bioshield separation (5 minutes after sun acquisition)	Indirect-only as it affects suballocation	Neg.
1.4	S/C	Design and control of Injection, Mid-course, Mars Orbit Insertion, and Orbit Trim Maneuvers and Reliability of associated Hardware and Software	Indirect-only as it affects suballocation	Neg.
1.5	Orbiter	Maintenance of Orbital Lifetime via control of orbital parameters and hardware design which minimizes explosion or spin-up.	Neg.	Neg.
1.6	Bioshield Base	Maintenance of Orbital Lifetime via control of orbital parameters.	Neg.	Neg.
2.0	Lander	Reduction of buried viable organisms by component heat treatment and subsequent reduction of entire Lander bioburden by heat treatment (sterilization) and maintenance of Lander sterility by maintaining bioshield pressure and maintenance of Lander sterility by S/C design and flight operations	Strong and Direct (S&D)	Strong and Direct (S&D)

TABLE 1.1 (cont.)
VIKING '75 PP MATRIX

REQUIREMENT		IMPLEMENTATION APPROACH	Degree of Dependence On	
NO.	NAME		P(g)	Biology Experiment Requirements
2.1	Lander Sterilization	Optimization of Approach to minimize sterilization impact via thorough studies, measurements and tests.		
		a) Development of reliable, dry heat sterilizable hardware	S & D	S & D
		b) Thermal analysis and measurement at the component, subsystem, and Lander levels to assure accurate knowledge of the thermal response of the components and the Flight Landers during sterilization cycles.	S & D	S & D
		c) Analysis and computerized book-keeping system to support pre-sterilization bioburden calculations by maintaining accurate information on "as built" composition of each Lander.	S & D	S & D
		d) Component dry heat treatment to reduce buried bioburden- accomplished as part of flight acceptance testing.	S & D	S & D Neg.
		e) Sequential bioassay milestones to support bioburden determination	S & D	S & D
		f) Design, development, fabrication, test, and use of complete sterilization facilities, procedures and verification instrumentation prior to sterilization of flight Lander.	S & D	S & D
		g) Analysis, design, development and testing of special requirements for the Biology instrument including the: MSS Sample Path, MSS plumbing, nutrient reservoirs, nutrient pressurant, PDA sample path and collector head.	Independent	S & D

TABLE 1.1 (cont.)
VIKING '75 PP MATRIX

REQUIREMENT		IMPLEMENTATION APPROACH	Degree of Dependence On	
NO.	NAME		P(g)	Biology Experiment Requirement
		h) Dry heat sterilization of flight landers under controlled and verified conditions	S & D	S & D
2.2	Maintain Lander Sterility from end of Sterilization cycle thru exit from earth's atmosphere and transfer to Mars	Prevent recontamination by;		
		a) Enclose Lander, prior to sterilization, in a sealed, protective container (bioshield)	S & D	S & D
		b) To compensate for seal leaks within tolerance and inadvertent bioshield leaks, maintain interior of bioshield at a positive pressure through the <u>continuous</u> introduction of sterile nitrogen gas: <ul style="list-style-type: none"> - during sterilization - during residence at the SAEF - during transfer to the launch complex - during hoisting to the top of the Launch Vehicle - during prelaunch ops. 	S & D	S & D
		c) Thermal control for the Lander requires continuous flow of a liquid coolant to the RTG's within the lander. This is, in effect, a sterile insertion operation. Viking used an approach which gave high assurance the fluid lines would not leak and provided for the use of water until 7 days before launch at which time a liquid sporicide was used as the coolant. This activity commences at sterilization & terminates 11 minutes prior to launch, at which time the lines are blown out with hot sterile nitrogen.	S & D	Weak & Indirect

TABLE 1.1 (cont.)
VIKING '75 PP MATRIX

REQUIREMENT		IMPLEMENTATION APPROACH	Degree of Dependence On	
NO.	NAME		P(g)	Biology Experiment Requirement
		<p>d) The Lander hydrazine propellant was not heat sterilized with the Lander since it had been demonstrated to be sporicidal. However, the operation of its post sterilization insertion into the lander had to be designed & implemented as a sterile insertion procedure. This also is true for the nitrogen propellant gas--i.e. sterile nitrogen (filtered) had to be introduced into the Lander via "sterile insertion" techniques.</p>	S & D	Weak & Indirect
		<p>e) Lander recontamination is a strong function of the Orbiter surface bioload. This load was maintained low from encapsulation in the nose fairing through launch by the continuous introduction of Class 100 air during all intermediate operations (i.e. transport to the pad, hoisting, etc.).</p> <p>The actual levying of this requirement was not however, by either PQ or Biology Science.</p>	(Special Case - by others but to both PQ &	Requirement beneficial to Biology)
		<p>f) To prevent damage to the bioshield and subsequent Lander recontamination during the short pressure reversal which occurs during launch, Viking designed, qualified and used a special biofilter vent in the bioshield. This biofilter vent prevented recontamination of the lander during launch.</p>	S & D	S & D
		<p>g) The project chose to eject the bioshield cap early in the heliocentric transfer phase. The design of the lander & orbiter was such that this could be achieved without exceeding the lander recontamination allocation, providing all portions of the lander were exposed to lethal UV radiation.</p>	S & D	Moderate & Direct

TABLE 1.1 (cont.)
VIKING '75 PP MATRIX

REQUIREMENT		IMPLEMENTATION APPROACH	Degree of Dependence On	
NO.	NAME		P(g)	Biology Experiment Requirement
		g) (cont.) To assure this, a 180° roll maneuver was performed half way through the de-orbit coast.		
3.0	Ejecta-Efflux	Viable microorganisms in or on s/c ejecta could contaminate Mars. Viking assured and demonstrated that these potential contaminating events were less than the assigned suballocations by:		
		a) Controlling the maximum allowable bioburdens on the s/c by taking advantage of cleans/c hardware & propellant, clean room procedures and class 100 air supplied to the nose fairing.	S & D	Negligible
		b) Extensive analysis - using experimentally obtained data and/or approved parameters & analytical techniques - of all possible ejecta contaminating events to show that their probabilities were less than the assigned suballocations.	S & D	Negligible

1.2 _ Review of 1984 Mars Mission Preliminary Planning_

This section discusses our review of preliminary planning activities in order to identify new or different aspects of the earliest post Viking Mars mission receiving serious study. Major sources of information reviewed were the "Preliminary Mars '84 Rover System Point Design Description - April 25, 1977" and the "Preliminary Mars Surface Penetrator System Description, May 1977".

This review identified major items, or categories of items, which appeared to have a meaningful interface with PP. These items are listed in Table 1.2-1 and the nature of the PP interface is briefly discussed in the following paragraphs. No attempt is made in this section of the report to evaluate the impact, if any, of these new features; the intent is merely to identify them.

TABLE 1.2 - 1

NEW FEATURES OF 1984 MISSION HAVING POTENTIAL
PP INTERFACE

NO.	I T E M
a)	1983/'84 Launch Date
b)	1 Year Rover Lifetime
c)	New (Post Viking) Hardware
d)	Rover Mobility
e)	Shuttle (STS) Launch
f)	Drilling
g)	Deployable Science Package
h)	Complex Thermal System
i)	Penetrators
j)	Biology Experiment
k)	Imaging System - Microscope

a) 1983/'84 Launch Date

b) 1 Year Rover Lifetime

c) New (Post Viking) Hardware

These three items are discussed together since their general interface with PP is that they all result in logical impediments to the direct transfer of successful Viking technology to an '84 Rover Mission. The author has heard directly, as well as indirectly, from knowledgeable people connected with Viking that the necessity to sterilize the Lander helped achieve high reliability

and did not significantly add to the cost. Conversely, for more than a decade there has been strong resistance - - from a reliability and cost standpoint - - to heat sterilization of spacecraft. The tremendous success of Viking provides a strong argument for essentially duplicating Viking technology for an '84 Rover Mission. However, the eight year time span from the Viking launch to the 1983/'84 Rover launch window certainly will result in improved technology in many areas. This technology will potentially offer improvements in lower costs, less weight, better reliability, etc. Similarly, the requirement for the Rover to perform for one Martian year after landing - as opposed to the 90 day Viking Lander requirement - will also present arguments for incorporating new technology to meet the longer lifetime requirements. The third new feature arises from the use of totally new components or systems not included in Viking, for example, the mobility system, drilling, the deployable science packaging, etc.

In summary, the three features discussed above all provide arguments on the necessity for using new s/c technology. An input to the decisions regarding these items will be the PP requirements that any new s/c technology will have to meet. The development or use of new PP technology is not envisioned since the PP technology developed and successfully used on Viking and/or earlier planetary programs (aim point biasing, dry heat sterilization, etc) should prove sufficient to allow all PP requirements to be met.

d) Rover Mobility

Since this is a new feature for the '84 Rover mission, all hardware will be new as discussed above in (c). A different interface, however, occurs with PP because of the Rover's mobility. A major reason for the mobility is to search out interesting areas for detailed study - both during this mission as well as future missions. Hence, in effect, any microbiological contamination contained in or on the Rover has a higher probability of contaminating interesting microenvironments on Mars than the Lander and consequently will require either relatively more decontamination or a larger probability of contamination allocation. This is almost directly analogous to the Orbiter vs. Lander treatment on the Viking Mission.

Another aspect of the Rover mobility is that, in effect, the Rover provides another mechanism for transportation of Earth microbial contamination on Mars (other than Mars winds); hence, it actually enters into the thinking concerning the value and application of $P(g)$ since one term which enters into the definition of $P(g)$ is the transport term.

e) Shuttle Launch

As discussed in Task 1.1 of this report, two areas of PP interface are involved in the time between the sterilization of the Lander and the exit of the s/c from the Earth's atmosphere.

One area concerns recontamination of the Lander (see Table 1.1 No. 2.2, (a) through (g)). The second area concerns the bio-load on the exterior of the Orbiter and the Bioshield (see Table 1.1 No. 3.0 (a) and (b)). Both of these areas are affected by the use of the Space Transportation System (STS) in lieu of the Titan III launch vehicle and will require new or modified approaches and/or redistribution of the PP contamination suballocations to assure that PP requirements will be met.

f) _ _ Drilling

This interface with PP is analogous to the cases of the Orbiter vs Lander and the Lander vs. Rover (pointed out under the Rover Mobility) in the sense that drilling activities occur in direct proximity with the most contamination critical area (areas that are of potential biological interest). Also, this activity has a direct bearing on the reasoning entering into the definition of P(g) since it provides a transport mechanism for microbial contamination on Mars. Special treatment for this activity might be required.

g) _ Deployable Science Package

Although this item is new, not much can be said about it because of the limited definition available. A heat flow probe, if intended to probe into the Mars surface, has a similar PP interface as discussed above under Drilling.

h) Complex Thermal System

Although many features and requirements of this system are similar to Viking, there are new thermal aspects such as; the shuttle launch environment, the Rover thermal control requirement and thermal control of deployable science packages. Complex thermal questions will arise, similar to those discussed for Viking in Section 1.1. They will include methods used to dry heat sterilize the Lander; extensive thermal testing needed to verify thermal performance during sterilization and the sterile insertion nature of introducing the RTG coolant fluid from presterilization through separation at the time of cargo deployment.

i) Penetrators

Mars Penetrators are essentially a special type of Mars Lander and will therefore require similar decontamination and prevention of recontamination as the Lander/Rover. The Penetrator RTG coolant, if required, will have to be treated as a sterile insertion operation as on the Lander/Rover. The existing parameters for the probability of microbial release will need review to determine if the special landing method used by the penetrator is covered. Finally, a unique PP interface arises because of the ability of the penetrators to serve as a transport mechanism for microbial contamination capable of going to possible hospital environments (i.e., protected from UV and containing water).

j) Biology Experiments

At this point there does not appear to be any firm definition as to the nature of the biology experiments which would be on-board an '84 Rover Mission. The exact nature of a requirement to protect the biology experiment cannot, therefore, be stated in detail. However, it is reasonable to assume that any biology experiment would require contamination protection similar to the Viking experiment. In that case, all hardware in contact with the sample path required extensive decontamination treatment along with thorough steps to prevent recontamination. The latter steps were intimately dependent on the decontamination of the overall Lander. Furthermore, the mobility of the Rover will enter into the determination of the recontamination prevention steps to be implemented for Biology experiments on a Rover Mission.

k) Imaging System - Microscope

The Imaging Microscopy Science package may, depending on resolution and other performance parameters, provide useful information for Biology. This capability, if it exists, may require microbial contamination prevention measures.

1.3 Viking Science Results

Viking, as well as all previous U. S. Mars missions, was developed and operated under PQ requirements established prior to the availability of knowledge gained from experiments performed in the atmosphere and on the surface of Mars. This section of the report briefly discusses impressions of our review of the preliminary Viking Science results. The review covered most of the presently published material.

At the appropriate time, it is assumed that NASA and its advisory bodies will evaluate the Viking Science results and make any changes in PQ requirements which they deem warranted. It is not the intent of this section to predict or pre-empt such activity; rather, this section primarily is oriented to identifying the items which bear on possible future PP requirement modifications.

Our study revealed the following as some tentative results which might enter into the thinking relative to future PP requirement modifications:

- Failure to detect organic compounds
- Unusual, complex, active surface ---not understood--- possibly chemical activity, likely to be oxidizing

- Surface activity also found to depth of trench
- Northern permanent polar cap -- appears to be frozen water
- Presence of molecular nitrogen in Martian atmosphere
- Apparent higher water content of subsurface soil
- Atmospheric water vapor climatic changes
- Similarly of characteristics at both landing sites.
- Statistically limited biology experiment data

2.0 INTEGRATION OF STUDY TASKS, CONCLUSIONS AND RECOMMENDATIONS

Most of the information reviewed during the performance of this contract fell logically into one of the three previous sections of this report. Two additional factors arose during the study which will bear on PP requirements for future Mars missions. These items are Organic Contamination Control (OCC) and the general area of spacecraft cleaning. The first item, as mentioned earlier in this report was not a part of this study. However, we feel that OCC was a major element in the implementation of Viking and will most likely be an even more important factor in implementing future Mars missions based on the Viking science results to date. The second item, spacecraft cleaning, permeates OCC, Biology Science, and PQ and hence is currently under review, by others, and was therefore not specifically separated out in this study. However, it appears very likely that future PP requirements for Mars missions will have specific cleaning requirements, similar to those used on Viking, independent of any other PP requirements.

The method used to integrate the three subjects reviewed in this study (Sections 1.1, 1.2, and 1.3) was to pose some "what if" questions. The results of Section 1.2, new features of an '84 Rover mission, and the results of Section 1.3, Viking Science preliminary data review, led to the selection of a list of the "what if" questions to be asked.

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- ✓ 954439 Avco Lycoming Corp. - Interim Report, August 26, 1977
- ✓ 954442 Motorola Inc. - Seventh Quarterly Progress Report, October 26, 1977
- ✓ 954458 Rockwell International - Final Report, October 24, 1977
- ✓ 954471 Stanford Research Corp. - Quarterly Progress Report, September, 1977
- ✓ 954475 Texas Institute - Final Report, March, 1977
- ✓ 954527 Springborn Laboratories - Fifth Quarterly Progress Report, August, 1977
- ✓ 954559 Dow Corning - Fifth Quarterly Report, August, 1977
- ✓ 954589 Westinghouse - Fourth Quarterly Report, June 1977
- ✓ 954605 Sensor Tech., Inc. - Third Quarterly Progress Report, September, 1977
- ✓ 954607 General Electric Corp. - First Quarterly Progress Report, October 5, 1977
- ✓ 954653 Lockheed Missiles and Space Co., Inc. - Final Report, October, 1977
- ✓ 954694 Spectrolab - Third Quarterly Report, November 15, 1977
- 954706 ✓ 954720 ILC Dover - Final Report and Supplement to the Final Report, July 4, 1977
- ✓ 954721 Sheldahl - Final Report, June 22, 1977
- ✓ 954807 ✓ Exotech Research Inc. - Final Report, August 31, 1977

Very truly yours,

Joseph A. Wynecoop

for Joseph A. Wynecoop, Manager
Information Support Section
Technical Information and
Documentation Division

cc: Jerry Waldo, Acquisitions

* Including 954700 AEC-ABLE Engineering Company, Inc.
Final Report, October 20, 1977

The questions picked to be examined bear on three points:

(a) the value of $P(g)$, (b) the nature of any on-board biology experiments and (c) the degree of interest in protecting options for future life detection experimentation. Based on our study we have defined a probable range for each of these "what if" questions as follows:

- | | | |
|----------------------------------------------------------------------------------------------|---|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| (A) $P(g)$ - - - - - | { | <ol style="list-style-type: none">1. Gets very small, i.e., $\ll 10^{-10}$2. Intermediate3. Stays the same, i.e., 10^{-6} |
| (B) Nature of On-Board Biology Experiments - - - - - | { | <ol style="list-style-type: none">1. None2. Intermediate3. Of the importance and magnitude of the Viking Biology Experiments |
| (C) Degree of Interest in Protecting Options for Future Life Detection Experiments - - - - - | { | <ol style="list-style-type: none">1. None2. In "global" terms none, but high in special microenvironments3. As strong as it has been for for past decade. |

In each of the ranges the two extremes are fairly clear and probably reasonably valid as end points for the range. In all cases the intermediate point is essentially undefined and, in fact, can be any of several different values. For example, changes of $P(g)$ to 10^{-7} , 10^{-8} , 10^{-9} would all result in different specific

"answers" and in turn details of the answers would be developed over a period of time by the flight project organization.

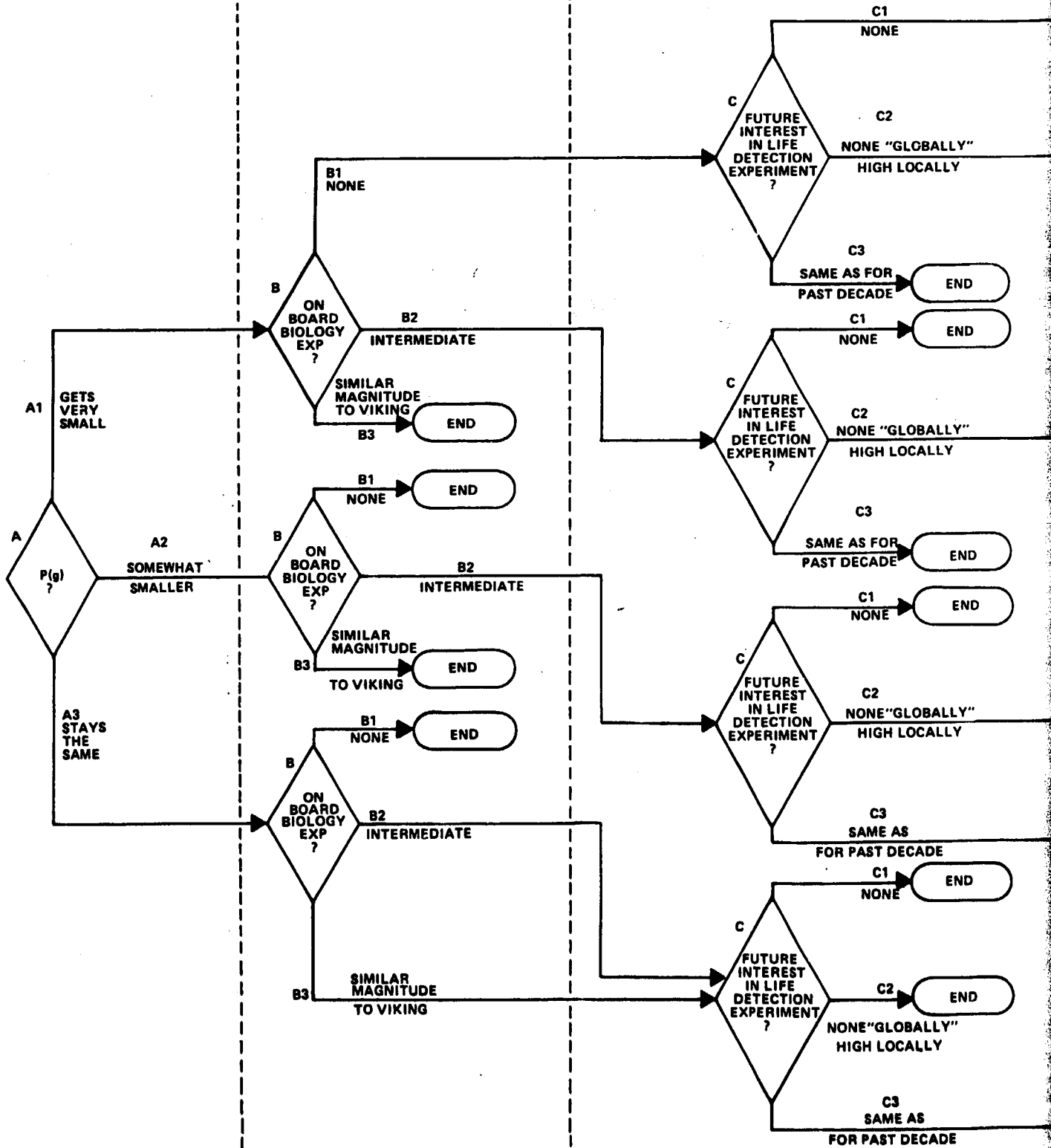
Permutations of the above questions result in 27 "what if" questions. However, in order to reduce this number we have eliminated many combinations which do not appear too likely to happen or do not appear logical. The reduced number of 9 "what if" questions were then reviewed against the Viking PP requirements presented in Section 1.1. The 9 "what if" questions, their "answers" and recommendations for future study are shown in Figure 2.

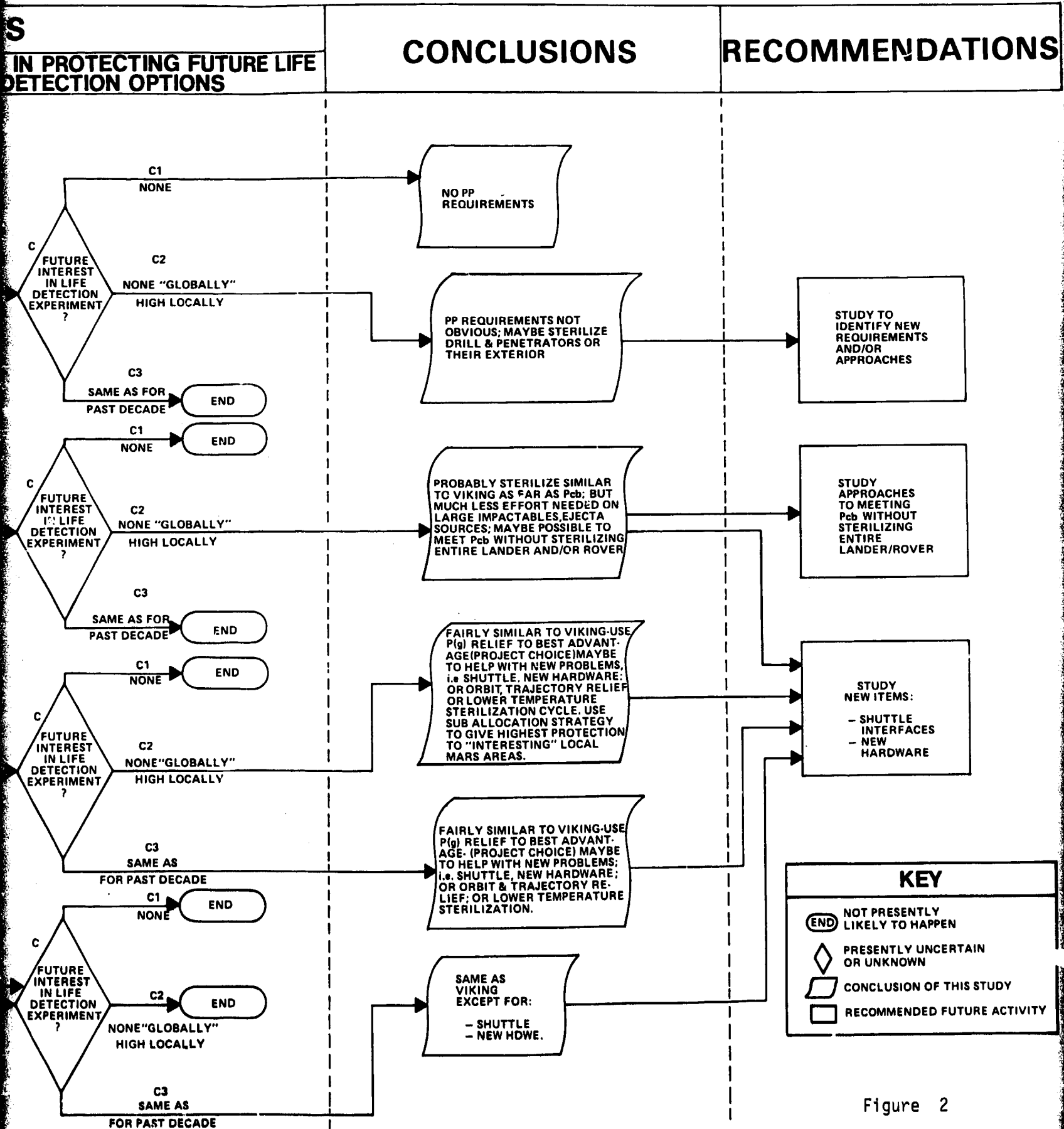
It is interesting to note that four of the six conclusions shown in Figure 2 lead to one common recommendation; namely, study new items, particularly the Shuttle Interfaces and new s/c hardware. This commonality of recommendations is somewhat similar to the situation in the 1960's. At that time certain PQ research and development was being pursued because it appeared to offer broad-based results which would be applicable regardless of the specific PQ requirements which might have evolved.

In summary, all the conclusions of this study, except one, are shown in Figure 2. The one conclusion not shown is that there is likely to be a general PP cleaning requirement imposed on all future Mars missions.

"WHAT IF" QUESTIONS

P(g)	ON BOARD BIOLOGY EXPERIMENT	INTEREST IN PROTECTING FUTURE LIFE DETECTION OPTIONS
-------------	------------------------------------	-------------------------------------------------------------





KEY

- END NOT PRESENTLY LIKELY TO HAPPEN
- ◇ PRESENTLY UNCERTAIN OR UNKNOWN
- ▭ CONCLUSION OF THIS STUDY
- RECOMMENDED FUTURE ACTIVITY

Figure 2