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A Proposed New Policy for Planetary Protection

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ABSTRACT

A planetary protection policy is being developed with the intention of reflecting the current state of the NASA planetary exploration program and the knowledge of the solar system. In this development study, a critical review of the present policy was conducted with emphasis on its application to future planetary exploration. The probable impact of recent data on the implementation of the present policy was also assessed. The existing policy and its implementation were found to: 1) be excessive for certain missions (e.g., Voyager), 2) neglect the contamination hazard posed by the bulk constituent organics of spacecraft, 3) be ambiguous for certain missions (e.g., Pioneer Venus), and 4) treat all extraterrestrial sample return missions alike.

The major features of the new policy are planet/mission combinations, a qualitative top level statement, and implementation by exception rather than rule. The concept of planet/mission categories permits the imposition of requirements according to both biological interest in the target planet and the relative contamination hazard of the mission type. This narrow construction provides for the general replacement of the quantitative analysis required under the present policy with qualitative requirements, for the elimination of all implementation requirements for most planetary missions and for the simplification of the remaining compliance procedures.

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EXECUTIVE SUMMARY

The beginnings of planetary protection occurred in 1956 with attempts to plan for the prevention of lunar and planetary contamination. Due to the concern expressed over impending space exploration activities, an international program involving a treaty, international law and national policy statements was developed. The present U.S. NASA Planetary Protection Program is based on that treaty and on the NASA Policy Directive, NPD 8020.10A. Basic NASA implementation requirements are presented in "Quarantine Provisions for Unmanned Extra-terrestrial Missions," NHB 8020.12A (original issuance 1969, revised 1976). Other than occasional revisions of the probability of growth parameters, used to calculate the probability of planetary contamination, the approach to planetary protection has changed little since 1972.

The basic NASA policy (and the treaty) established a probability criterion of one in one thousand ($1x10^{-3}$) for contaminating a planet of biological interest during the period of biological exploration. The standard procedure for compliance by a flight project has consisted of analyzing the probability of contaminating the target planet to demonstrate that the value is less than the project's assigned allocation for the planet. This quantitative approach has inherent weaknesses including the uncertainty in the required input parameters (especially the probability of growth) and the dependence of the mission allocation on the predicted number of future explorations of the target planet. In addition the wealth of data obtained by planetary exploration during this decade has consistently been negative on the existence of indigenous life forms on other planets. The environmental findings have also reduced estimates of the probability of growth to the point that no planetary protection implementation is required for the outer planets and their satellites under the current provisions. However, organizations such as the Committee on Space Research (COSPAR) and the Space Science Board (of the U.S. National Academy of Sciences) have recommended baseline requirements in these cases by implication (e.g. cleanrooms).

Basically the present planetary protection policy and requirements have served well over the years. However, recently derived small and uncertain values of the probability of growth severely strain the probabilistic approach. Additional information obtained has led to added provisions and requirements on a case by case basis. These changes have weakened the logic of the program and occasionally caused inconsistencies. Now each new flight project must negotiate special requirements and parameter values and will frequently seek waivers from the Planetary Protection Officer.

The planetary protection policy and requirements described and proposed in this report are responsive to the criticisms outlined above in that they reflect more closely the present knowledge of the planets and other solar system bodies, and are consistent with the number and types of missions planned. The proposed basic policy eliminates all reference to probability of contamination, and might be expressed by the following:

> Although the existence of life elsewhere in the solar system may be unlikely, the conduct of scientific investigations of possible extraterrestrial life forms, precursors and remnants must not be jeopardized. In addition, the Earth must be protected from the potential hazard posed by extraterrestrial matter carried by a spacecraft returning from another planet. Therefore, for certain space mission/target planet combinations, controls on contamination shall be imposed in accordance with issuances implementing this policy.

This change permits significant de-emphasis on the use of mathematical models and quantitative analyses in the requirements. The concept of target planet/mission type categories is also introduced. With this concept both the contamination threat posed by the type of mission (i.e. fly-by, orbiter, lander or probe) and the degree of biological interest in the target planet may be considered in the establishment of requirements by category.

Category I essentially corresponds to the present class 1, i.e. any type of mission to a target planet of no biological interest. In effect no protection of such planets is warranted and no planetary protection requirements are imposed.

Category II missions comprise all types of missions to those target planets for which there is minimal biological interest and an opinion among the scientific community that there is a remote chance of contamination carried by a spacecraft or associated hardware jeopardizing a future biological experiment. The requirements are for simple documentation only. Flight projects will be required to prepare a short Planetary Protection Plan primarily to outline intended or potential impact targets, brief pre- and post-launch analyses detailing impact strategies, and a post-encounter or end-of-mission report which will provide the location of impact if such an event occurs.

Category III missions comprise some missions to a target planet of biological interest or for which scientific opinion provides a significant chance of contamination jeopardizing a future biological experiment. The types of requirements will consist of documentation (more involved than Category II) and some implementing procedures including trajectory biasing, the use of cleanrooms during spacecraft assembly and testing, and occasionally bioburden reduction. Although no impact is intended for Category III missions, an inventory of bulk constituent organics will be required if an impact occurs.

Category IV missions comprise some missions to a target planet of biological interst or for which scientific opinion provides a significant chance of contamination jeopardizing future biological experiment. Category IV is the subset of such missions where direct contact with the target planet at issue is intended. Requirements imposed will include rather detailed documentation (more involved than Category III), an increased number of implementing procedures, a bioassay to enumerate the bioburden, a probability of contamination analysis and an inventory of the bulk constituent organics. The implementing procedures required would include trajectory biasing, cleanrooms, bioload reduction, possibly partial sterilization of the direct contact hardware and a bioshield for that hardware. Generally the requirements and compliance will be similar to Viking, with the likely exception of complete lander/probe sterilization.

Category V missions comprise all Earth return missions. The concern for these missions is the protection of the terrestrial system, the Earth and the Moon. (The Moon must be protected from back contamination to retain freedom from planetary protection requirements on Earth-Moon travel.) For the set of planets deemed by the scientific community to have no indigenous life forms, a special subcategory "safe for Earth return" is defined. Missions in this subcategory will have planetary protection requirements on the outbound phase only, corresponding to the category of that phase (typically category I or II). Such flight projects will have to formally request this categorization from the Chief, Planetary Protection Program. For all other Category V missions,...the highest degree of concern is expressed by the absolute prohibition of impact, the need for sterilization of returned hardware which directly contacted the target planet, and the need for containment of any unsterilized sample collected and returned to Earth. In general this concern is reflected in a range of requirements that encompasses those of Category IV plus a continuing monitoring of project activities and pre-project studies and research (e.g., in remote sterilization procedures and containment techniques). The requirements for the protection of Earth have been and continue to be the subject of a number of studies which will eventually lead to their detailed definition.

From the definitions of the categories, it is clear that all possible target planets must be assigned a planetary protection priority. The proposed prioritization, according to biological interest and contamination concern, is based on the best available scientific judgement. The overall development of proposed categories is summarized and the proposed priorities of the planets are presented in the accompanying table, "Proposed Categories for Planets and Types of Missions."

The implementation of the proposed policy will adopt a more direct yet less generic means of levying requirements. It will be more direct because it will establish requirements by target planet/mission class combinations, and less generic because it will utilize more specific and more numerous categories than existing implementation. There will be no baseline requirements across categories either in terms of documentation or hardware requirements. Additionally, because the new policy is not quantitative, there will be categories of planet/missions with no quantitative requirements. Under the new policy, quantitative requirements will be levied exceptionally on those planet/mission combinations which warrant them. It is anticipated that only the combination involving Mars and Earth will be the exceptions. As is the case with existing implementation procedures, a revised version of NHB 8020.12A will be the governing document.

The new policy and its implementation will assign clear, direct roles and responsibilities to the Associate Administrator for Space Science and the Planetary Protection Officer to ensure that NASA's Planetary Protection Program is a program of the agency and not any of its parts.

A series of reviews and presentations regarding the new planetary protection policy will be conducted prior to the preparation of formal NASA documents defining the policy and assigning responsibility for its execution. The new NASA policy will be presented to the international community during COSPAR's 1982 meeting in Ottawa, Canada.

The major impact of the proposed planetary protection policy will be in the implementation and methods of compliance by future planetary missions. Specific spacecraft missions currently under consideration include: Galileo, a comet fly-by or encounter, International Solar Polar Mission (ISPM), Venus Orbiting Imaging Radar (VOIR), Saturn Orbiter with Twin Probes (SOP2), and a Mars Surface Sample Return Mission (MSSR). Because NASA has determined that all future planetary spacecraft will be launched by the Space Transportation System (STS), it is important to evaluate the proposed policy in light of the new launch system.

Under the proposed policy, Galileo Project would be a Category II mission. No contamination control procedures would be required for planetary protection. However, the Project would be encouraged to provide some contamination control in its own interest. There would be a requirement to document for the record the planned contamination control and to reference the expected contamination impact (microbial load) of STS operations.

Any cometary mission (except for a sample return mission) would be placed in Category II under the new policy, thereby resolving the issue of classification for this type of mission which currently exists. The general requirements would be for documentation only. A cometary sample return mission would be a Category V mission, and unless declared "safe for Earth return" would be required to comply with all planetary protection provisions of that Category (See following section on MSSR).

The ISPM would also be a Category II mission. There would be no requirement for any analyses, assay or contamination control. Again, the general requirements would be for documentation only.

Under the proposed policy, VOIR would also be placed in Category II. There would be no requirements for analyses, assays, contamination control or microbial burden reduction. Documentation requirements would apply.

A Saturn orbiter with twin probes would be a Category II mission requiring documentation only. The detailed documents would be similar to that of Galileo.

Because MSSR is a mission where a spacecraft is landed on Mars and part or all of the landed hardware is returned to Earth, it must comply with planetary protection provisions which pertain to the protection of future science at Mars and to the protection of Earth against back contamination. Therefore, MSSR would be a Category V mission. Requirements for the outbound portion of the mission will be similar to those imposed on and implemented by the Viking Project, with the possible exception of sterilization of the complete lander/probe.

Generally, the outbound phase of an MSSR mission will be favorably impacted by the new planetary protection policy. Requirements will be somewhat relaxed from those imposed on Viking under the old policy and implementation. The other two phases of the mission (sample acquisition/delivery and science/quarantine investigations) will be seriously impacted by the new policy not in relative terms, since there never was a formal policy addressing those phases, but in terms of the anticipated range of requirements deemed essential for affording Earth the same protection, at the very least, as is provided for planets of interest. The extent of this impact on an MSSR project will depend on the severity of specific requirements to be developed in the near future.

For missions where the policy requires either a microbiological assay or a microbial burden reduction, the features of the STS ground and launch operations pose a problem. For Category III missions, the requirement for passive bioload control in the face of an STS launch will be definitely reflected in the PP implementing issuances. In this case, not only must the expected contamination due to standard STS operations have been previously determined (as needed for Category II), but also the efficacy of special contamination control procedures. These contamination control procedures would be documented as requirements in the implementing issuances for STS launched Category III missions.

For Category IV and Category V missions, the obvious recommendation is the requirement of a contamination shroud. This is a severe and costly requirement, but the only logical choice.

One final impact of the proposed policy on planetary missions is concerned with the protection of science instruments. In the past, the Planetary Protection Program has provided contamination control, cleaning and sterilization for certain biological instruments on an exceptional basis, specificially for the Viking mission. Under the proposed policy, the Planetary Protection Program will have no responsibility for, and will not provide, contamination control or bioburden reduction services for science payloads. In addition, the Planetary Protection Program will not be responsible for any damage to scientific instruments or for any morphological, chemical or biological changes in a returned sample caused by the project's implementation of planetary protection requirements.

The following table summarizes the proposed planetary protection policy and requirements, and highlights the key differences from the present program.

Comparison of Existing and Proposed Planetary Protection Policy

DEFINITION/REQUIREMENTS	EXISTING CONDITIONS	NEW IMPLEMENTATION
o Classification of Missions	o Missions are classified by mission type only (except Class 1)	o Missions are classified by mission type/target planet combinations
o General PP Requirements	o Apply to all missions except those to the Sun and Mercury	o Apply only to those missions to Mars, and returning to Earth
o Documentation Requirements	o Apply to all missions	o Detail required for missions to Mars, and returning to Earth only. Brief for other missions, except none for Sun, Mercury and Pluto.
o Biological Assays	o Apply to all missions except those to the Sun and Mercury	o Apply only to those missions to Mars, and returning to Earth.
o Quantitative Requirements	o Probabilistic in nature. Apply to all missions except those to the Sun and Mercury	o For the most part nonprobablistic. Apply only to missions to Mars, and returning to Earth.
o Expression of Degree of Concern	o Probability of growth	o Range of requirements

Proposed Categories for Planets and Types of Missions

	CATEGORY I	CATEGORY II	CATEGORY III	CATEGORY IV	CATEGORY V
Type of Mission	Any but Earth Return	Any but Earth Return	No Direct Contact (flyby, some orbiters)	Direct Contact (lander, probe, some orbiters)	Earth Return
Target Planet	Priority A Sun Mercury Pluto	Priority B Venus Jupiter Saturn Outer planet satellites Uranus Neptune Comets Asteroids Others	Priority C Mars	Priority C Mars	Any
Degree of Concern	None	Record of planned impact probability and contamination control measures	Limit on impact probability Passive bioload control	Limit on probability of non-nominal impact Limit on bioload (active control)	If <u>not</u> Safe for Earth Return: No impact of Earth or Moon Sterilization of returned hardware Containment of any sample
Representative Range of Requirements	None	- Documentation only • PP plan (brief) • Pre-launch report (very brief) • Post-launch report (very brief) • Post encounter report (very brief) • End of mission report (brief)	- Documentation (more involved than Category II) • Contamination control • Organics inventory (as necessary) - Implementing procedures such as: • trajectory biasing • cleanroom • bioload reduction (as necessary)	- Detailed documentation (substantially more involved than Category III) • P_c analysis plan • Microbial reduction plan • Microbiological assay plan • Organics inventory - Implementing procedures such as: • trajectory biasing • cleanroom • bioload reduction • partial sterilization of contacting hardware (as necessary) • bioshield - Monitoring of bioload via bioassay	<u>Outbound</u> - Per category of target planet/outbound mission <u>Inbound</u> If <u>not</u> Safe for Earth Return: - All of Category IV - Continual monitoring of project activities - Pre-project advanced studies/research If Safe for Earth Return: None

SECTION I

REVIEW OF PRESENT POLICY

Protection of celestial environments has been of scientific concern since it became technologically feasible to expl[illegible] the cosmos. With the accomplishment of space travel, man had to consider the possibility that undesirable life forms may follow him through his journeys. This concern over planetary contamination resulted in an international program of planetary protection which produced concomitant planetary protection requirements.

The development of existing planetary protection policy began in 1956 with the earliest attempts to prevent lunar and planetary contamination occurring at the VIIth International Congress of the International Astronautical Federation. From these early beginnings, a program designed to prevent contamination of the moon and planets by terrestrial microorganisms was established and implemented through various international and national policy statements, implementing issuances, and requirements covering space exploration.

A. HISTORY OF POLICY DEVELOPMENT

With the launch of Sputnik 1, the Soviet Union stunned the world and thrust entirely novel problems upon mankind. Subsequent to the international concern expressed over the harmful effects of planetary contamination resulting from space exploration, the U.S. National Academy of Sciences (NAS) established the Space Science Board (SSB) to "serve as the focal point for the interests and responsibilities of the Academy-Research Council in space science" (1). The SSB considered various problems concerned with the detection of extraterrestrial life and the prevention of planetary contamination with terrestrial organisms. In March, 1958, the Council of the NAS adopted and presented the following resolutions to the International Congress of Scientific Unions

(ICSU) (2):

> The launching of IGY satellites has opened space to exploration. Accordingly, attempts to reach the moon and planets can be anticipated, with reasonable confidence, within the foreseeable future.
>
> The National Academy of Sciences of the United States of America urges that scientists plan lunar and planetary studies with great care and deep concern so that initial operations do not compromise and make impossible forever after critical scientific experiments. For example, biological or radioactive contamination of extraterrestrial objects would easily occur unless initial space activities be carefully planned and conducted with extreme care. The National Academy of Sciences will endeavor to plan lunar or planetary experiments in which the Academy participates so as to prevent contamination of celestial objects in a way that would impair the unique and powerful scientific opportunities that might be realized in subsequent scientific exploration.
>
> The Council of the National Academy of Sciences of the United States of America urges the International Council of Scientific Unions to encourage and assist the evaluation of possibilities of such contamination and the development of means for its prevention. The Council of the Academy also requests the International Council of Scientific Unions to do whatever else it may to preserve and foster the unaffected potentialities of space research.

In presenting this statement, the NAS expressed its concern with the problems of celestial contamination resulting from space exploration, and pointed out the necessity for international cooperation to prevent alteration or destruction of extraterrestrial life forms.

In response to this request, the ICSU established an <u>ad hoc</u> committee on Contamination by Extraterrestrial Exploration (CETEX). This group recommended and urged acceptance of a code of conduct aimed at achieving a compromise between all-out space exploration and maximum protection of celestial bodies for future scientific studies. It also recommended that responsibility for overseeing planetary quarantine be placed with the newly formed ICSU Committee on Space Research (COSPAR).

In acceptance of this responsibility, COSPAR requested the U.S. and the U.S.S.R. to consider ways of avoiding contamination of celestial bodies. Following the request, numerous studies were performed that dealt with biological contamination, the survival of microorganisms in extraterrestrial environments, and means for the prevention of contamination. Foremost among these studies was a report by Davies and Comuntzis (3) which concluded that the problems of contamination should be viewed within the context of probabilities. Other studies and discussions centered around the probabilities of microbial survival in extraterrestrial environments, the need and techniques of sterilizing interplanetary vehicles, and contamination risks of space exploration.

Several papers (4,5,6,7,8) having important implications for guidelines concerning contamination control proposed mathematical models on which to base the probability of contamination and subsequent sterilization standards. Sagan and Coleman (9) analyzed the probability of planetary contamination and suggested sterilization standards based on the belief that: 1) there is little chance that life will be found on every mission, 2) accidental landing on the planet's surface may constitute a contamination hazard, and 3) biological contributions made by landers are greater than those made by flybys and orbiters. As a result of these studies the SSB recommended minimizing biological contamination of the moon to the extent technically feasible and established a probability of contaminating Mars during unmanned flight at 10^{-4}.

The COSPAR Resolution 26.5 was adopted at the 1964 COSPAR meeting. Using the Sagan-Coleman analytical model of contamination (9), the resolution accepted (10)

> ....as tentatively recommended interim objectives, a sterilization level such that the probability of a single viable organism aboard any spacecraft intended for planetary landing or atmospheric penetration would be less than 1×10^{-4}, and a probability limit for accidental planetary impact by unsterilized flyby or orbiting spacecraft of 3×10^{-5} or less.

Hall and Lyle (11) observed that COSPAR Resolution 26.5 was a

> ...milestone in that for the first time, there was international agreement on quantitative objectives in terms of probabilities of events which characterize planetary contamination. An analytical rationale thus was provided for the recommended standards and the quarantine problem as it was understood at that time. Although particulars of the COSPAR Resolution of 1964 have been reconsidered in the light of increasing knowledge, it provided a framework which continues to serve in the development of quarantine standards. The essential elements of the framework are: (1) a model of the principal parameters and their inter-relations; (2) agreements as to which parameters should serve as basic standards; and (3) assignment of quantitative values to the chosen parameters.

Although the United States Planetary Quarantine Program was implemented by the National Aeronautics and Space Administration (NASA) in response to the COSPAR requirements, the first formal NASA policy directive concerning protection of celestial bodies was issued in October 1959 by Dr. Abe Silverstein. This directive, in the form of letters, stated the following (12):

> The National Aeronautics and Space Administration has been considering the problem of sterilization of payloads that might impact a celestial body.
>
> Consideration was given to scientific questions, engineering problems, NASA's responsibility towards protecting scientific investigations into space, and the reputation and integrity of the United States. As a result of the deliberations, it has been established as a NASA policy that payloads which might impact a celestial body must be sterilized before launching.

Ranger, the first U.S. lunar flight project, was beset with difficulties. The series of failures aroused protest with claims that sterilization was in part responsible. A further directive on the subject "Decontamination and sterilization procedures for lunar and planetary space vehicles" was issued by T. Keith Glennan, Administrator, NASA, in December 1960. The directive stated that "effective decontamination and sterilization procedures for lunar and planetary space vehicles are essential." A change in policy was not issued until September 1963, when NASA issued its Management Manual NMI-4-4-1, "NASA Unmanned Spacecraft Decontamination Policy" (13). The management instruction stated that "cleanroom assembly policies be adopted, sporocidal agents be used when 'appropriate' to reduce surface contamination, and final assembly be wrapped and handled in such a way as to prevent accumulation of contamination during its shipment to the launch site" (14). Lunar spacecraft sterilization policies were thus abandoned and replaced by quarantine policies designed to prevent terrestrial contamination of the lunar samples and the possible introduction of alien life forms to the Earth's biosphere. Planetary missions continued to require sterilization.

NASA policy directives concerned with back-contamination and extraterrestrial exposure, as well as authority to deal with any cases which might occur, were implemented through NPD 8020.13 (15), NPD 8020.14 (16), NMD/A 8020.15 (17) and NMD/M 8020.16 (18). These provisions were designed to: 1) protect the Earth's biosphere from alien life forms, and 2) protect lunar samples from terrestrial contamination.

On September 6, 1967 NASA NMI-4-4-1 was replaced by NASA Policy Directive 8020.7, "Outbound Spacecraft: Basic Policy Relating to Lunar and Planetary Contamination Control" (19). This document stated that "Microbial life landed on the Moon... shall be identified, quantified and, insofar as possible, located [sited]". This would ensure that if life were found in returned samples, it could be identified as terrestrial.

In 1967 the United States became a signatory to an international treaty (20) which states in part that: "The basic probability of one in one thousand (1×10^3) that a planet of interest will be contaminated shall be used as a a criterion during the period of biological exploration..." The basic contamination control policy for planetary missions appeared in NPD 8020.10 (21) and was updated by NPD 8020.10A, "Outbound Planetary Biological and Organic Contamination Control: Policy and Responsibility" (22). The following provision was contained in both of these documents:

> Biological Contamination. The basic probability of one in one thousand (1×10^{-3}) that a planet of biological interest will be contaminated shall be used as the guiding criterion during the period of biological exploration of Mars, Venus, Mercury, Jupiter, other planets and their satellites that are deemed important for the exploration of life, life precursors or remnants thereof.

Planetary contamination by organic constituents was also addressed in NPD 8020.10A (22) by the following:

> Organic Contamination. In order to assist in the interpretation of the results of future scientific experiments, control of organic contamination shall be limited to accountability for organic materials deposited on a planet by a flight mission.

This provided that planetary conditions would be preserved for future organic constituent exploration as well as for biological exploration, and placed certain constraints concerned with organic material identification on flight projects. In other words biological interest in a planet was construed to include the concern for pre-biotic organic and remnant finds, as well as the classical search for indigenous life forms.

In accordance with NPD 8020.7 (19) and NPD 8020.10A (22), NHB 8020.12 (23) and later NHB 8020.12A, "Quarantine Provisions for Unmanned Extraterrestrial Missions" (24) established basic NASA requirements for the biological quarantine of celestial bodies. In line with international agreements, this document spoke in terms of the probability of contamination.

B. POLICY IMPLEMENTATION

The authority for implementation of national planetary protection policy resides with NASA, while basic responsibility for the program lies with the Associate Administrator for Space Science (19) as shown in Figure 1. Within this office, responsibility has been delegated to the Life Sciences Division (Figure 2). Although no formal documentation exists to such an effect, a direct line of communication has also been provided between the Planetary Protection Officer and the Associate Administrator, Office of Space Science. This organization has been alluded to, and practiced, in working relations for many years. The most recent example is the appointment of a Planetary Quarantine Officer directly by the Associate Administrator for Space Science (25). This organization provides a measure of autonomy from the Life Science Division and confers authority over flight programs.

In carrying out his responsibilities, the Planetary Protection Officer ensures compliance with NASA requirements established in NHB 8020.12A. As shown in Figure 3, planning, review, documentation and scheduling is established by this document.

The Planetary Quarantine Plan is the primary planning document describing how a planetary flight project will be conducted so as to avoid exceeding its planetary contamination allocation (expressed on the basis of probability). Based upon the type of mission and the total number of flights estimated to be conducted during the period of biological interest, the NASA Planetary Protection Officer allocates a portion of the U.S. share (by COSPAR resolution, 0.44×10^{-3} for each planet of interest) to each unmanned planetary mission. The planning document then includes a statement of mission class, the allocation for each planet involved in the mission, a mission description, the project suballocation to different mission hardware or phases (optional), a management plan, a list of pertinent documents, a list of facilities important in assuring planetary protection, and a schedule for planetary protection plans, reviews and documentation to be generated.

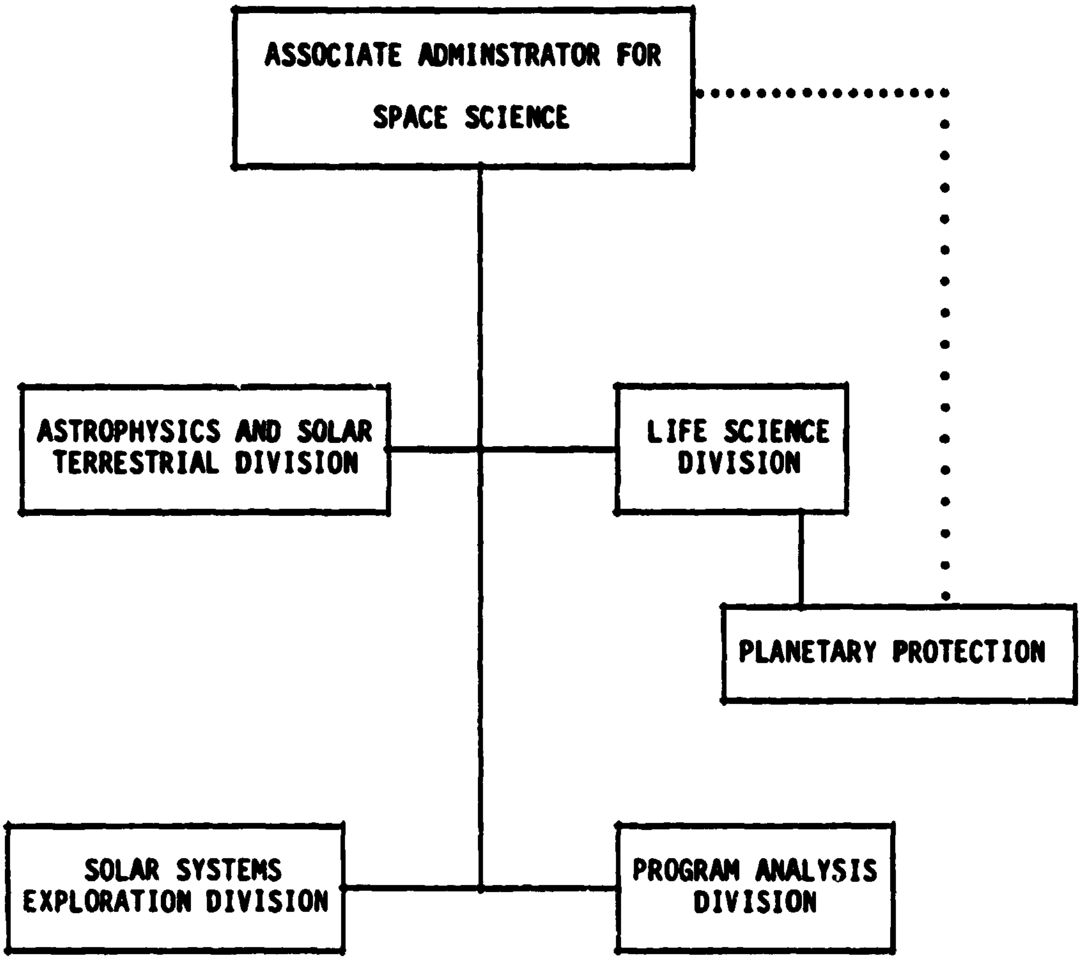


Figure 1. Organization of the Office of Space Science

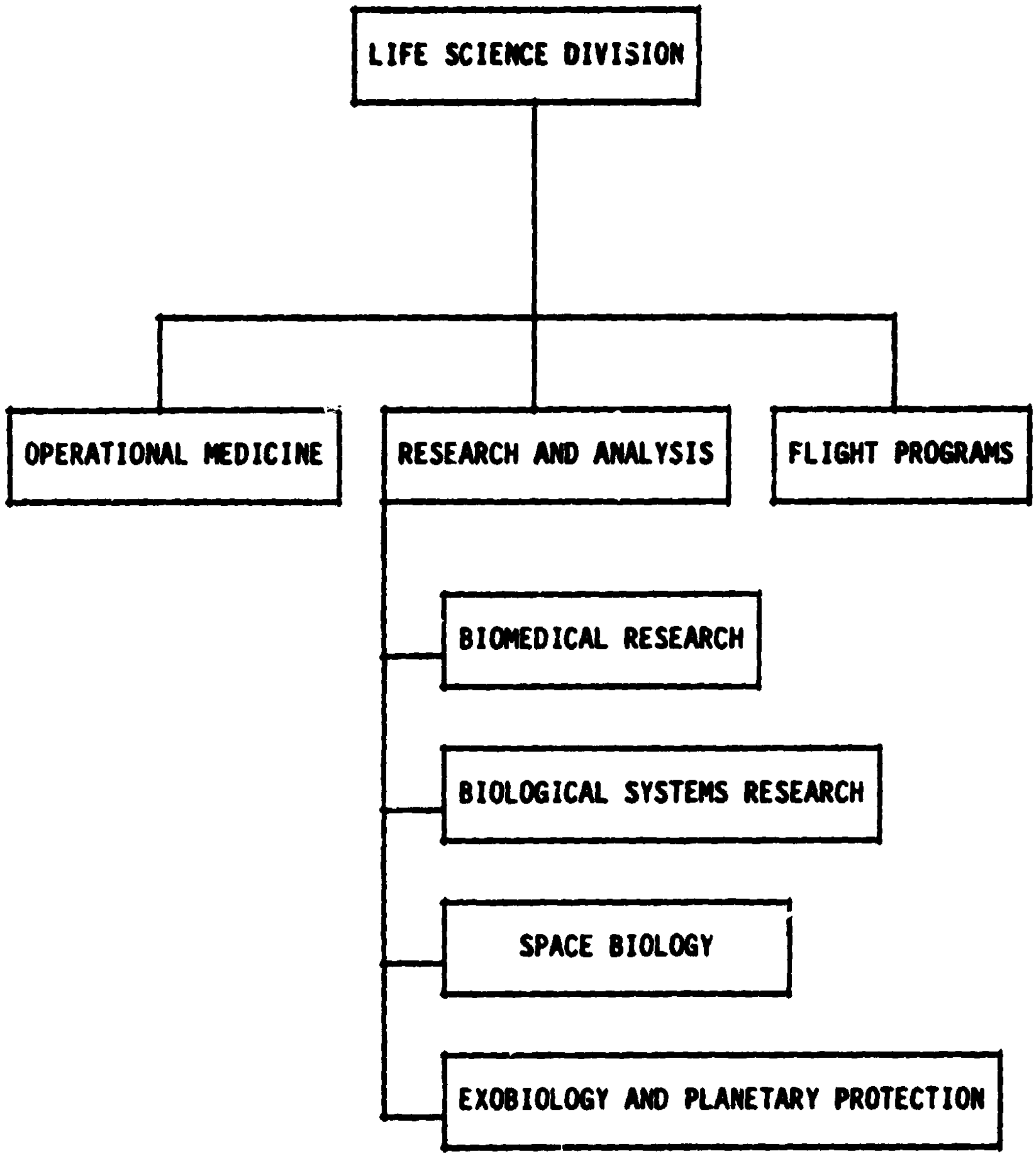
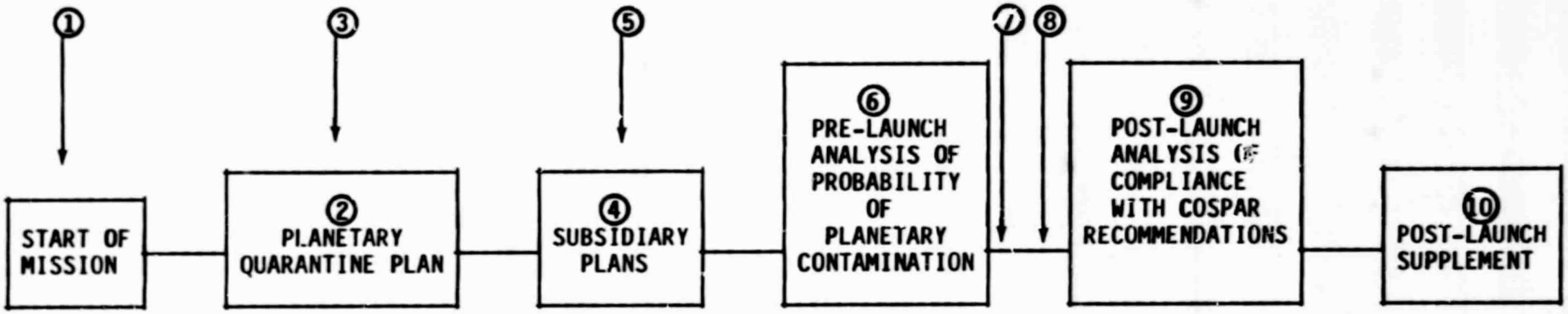


Figure 2. Organization of the Life Science Division, Office of Space Science



(1) Certification of Class 1 missions; to be accomplished within 60 days from project start.

(2) PQ Plan (draft); to be completed within 6 months after project start; planning document providing description of flight project and measures taken to avoid exceeding P_c allocation.

(3) Project PQ Planning Review; to be held within 60 days of release of PQ Plan.

(4) Subsidiary Plans (draft); to be completed within 9 months after project start, if applicable.

(5) Review of Subsidiary Plans; to be held within 60 days of release of draft version.

(6) Pre-Launch Analysis of Probability of Planetary Contamination; provides verification that PP requirements have been met and that the project can continue to satisfy them throughout the mission.

(7) Pre-Launch Planetary Quarantine Review; to be held no later than 90 days nor earlier than 120 days prior to the earliest scheduled launch date (essentially a review of (6)).

(8) Launch Readiness Review; assures continuing compliance with planetary protection requirements since (7) .

(9) Post-Launch Analysis of Compliance with COSPAR Recommendations; extends (6) to include effects of launch and early post-launch events.

(10) Post-Launch Supplement; submitted at formally declared "end-of-project", supplement to (9) documents degree to which PP requirements have been met.

Figure 3. Planetary Protection Requirements

In order to demonstrate compliance with planetary protection provisions, a Probability of Contamination Analysis Plan is submitted which shows how analyses will be performed to demonstrate compliance with the mission allocation and identifies all potential sources or mechanisms of contamination. The plan also includes what analyses will be performed, what formulas will be used, and the values of certain parameters used. One of the formulas currently used to calculate the likelihood of contaminating a planet by direct impact of the spacecraft is:

$$P_c = \sum_i m_i(o).P(vt).P(uv).P(a).P(sa).P(r).P(g)$$

where the typical parameters are:

P_c	The probability of contamination
$m_i(o)$	The initial microbial burden (at launch, after decontamination)
P(vt)	The probability of surviving space vacuum-temperature
P(uv)	The probability of surviving uv space radiation
P(a)	The probability of arriving at the planet
P(sa)	The probability of surviving atmospheric entry
P(r)	The probability of release
P(g)	The probability of growth.

The parameters used in this or other analyses may be specified by the Planetary Protection Officer, suggested and substantiated by the project, or taken from the NASA Planetary Quarantine Parameter Specification Book. The latter specifications were established through 1) research supported by the Planetary Protection Program, 2) recommendations of the Space Science Board, and 3) recommendations of the Planetary Quarantine Advisory Panel.

Two further requirements are imposed on unmanned planetary flight projects dependent on the mission class (Table 1): 1) microbiological assays, and 2) microbial reduction. For missions to which these requirements apply (mission classes 3 and 4), appropriate planning documents must be prepared. Microbiological assays are conducted during assembly of the spacecraft to enumerate the biological "burden" of the spacecraft and to ensure that the probability of planetary contamination will not exceed its allocation.

Typically, when estimates in the Probability of Contamination Analysis Plan indicates that a precise value of the microbial burden is needed (or for classes where assay is required), the flight project is required to conduct microbiological assays and must submit a Microbiological Assay Plan to the Planetary Protection Officer for approval. This document must identify the space vehicle hardware, facilities, and associated environments which are subject to assay, and demonstrate compliance with implementation procedures which appear in NHB 5340.1B, "NASA Standard Procedures for the Microbiological Examination of Space Hardware" (26). Quality assurance procedures used to ensure validity of assay results must also be described in the Plan.

Table 1. Designations of Mission Classes for Planetary Protection Purposes (22).

Mission Class	Mission Examples
1	Solar Mercury
2	Planet Flyby Gravitational Swingbys Planet Satellite Flybys Comet Flybys
3	Planet Probes Planet Landers
4	Sample Return from Planets or other Solar System Bodies

In order to meet P_c constraints, reduction of the microbial burden may be necessary. Microbial reduction involves hardware elements that must have their biological load reduced to a specified or measured level and is typically required due to estimates arrived at in the Probability of Contamination Analysis Plan. A Microbial Reduction Plan is required of all missions where the cleanliness level is critical (classes 3 and 4). The document includes the rationale for reducing the biological "burden," identification of the spacecraft hardware that is subject to microbial reduction processes, process analysis and verification and control, and a description of the methods for maintaining a reduced microbial level. The preferred method for achieving microbial load reduction is referred to as a "dry heat" cycle; i.e., a specified elevated temperature of a specified gaseous atmosphere for a specified length of time. Alternate methods such as chemical or radiation techniques may be proposed.

These plans (as required) are all submitted to the Planetary Protection Officer for review. Approval of the documents constitutes approval of the parameters developed and the methods proposed by a project for meeting planetary protection constraints.

To ensure that planetary protection activities are proceeding properly and in accordance with the planning documents, and to document compliance with planetary protection requirements, a project must accomplish a series of reviews and submit various reports to the Planetary Protection Officer.

A Pre-Launch Planetary Quarantine Review is conducted to ascertain that a flight project has met its planetary protection requirements to date, and to examine in detail related activities accomplished prior to the review. This review is based upon the Pre-Launch Analysis of Probability of Planetary Contamination document which includes a computation of the probability of contaminating the target planet based on the P_c allocation of the mission. This document also identifies all deviations from previously submitted plans, summarizes significant analytical and laboratory results relevant to demonstrating compliance with planetary protection constraints, identifies potential planetary protection violations which could occur throughout the mission, and verifies proper application of microbial reduction processes (as applicable).

Prior to the actual launch of the vehicle, a Launch Readiness Review, which includes planetary protection as a topic on the agenda, is held by a project. Significant planetary protection events, problems and changes which have occurred since the last review, as well as open action items, are addressed in this review.

A brief summary document, a Post Launch Analysis of Compliance with COSPAR Recommendations, based on the Pre-Launch Analysis of Probability of Planetary Contamination is submitted to indicate the degree to which the mission meets the overall planetary protection requirements through launch and early post-launch events.

In the case of multi-target planet missions, a Post-Encounter Analysis is performed to ensure continuing compliance with planetary protection requirements. This supplemental report to the Post Launch Analysis re-assesses the probability of contaminating the planet to be encountered next in light of events which occurred during encounter and early post-encounter events of the completed planet encounter. It might also be construed to be an end-of-project report for the portion of the mission completed.

A supplement to the Post Launch Analysis of Compliance with COSPAR Recommendations is submitted at the formally declared end-of-project. This document addresses the degree to which a mission has met planetary protection requirements throughout the complete mission.

SECTION II

OBSOLESCENCE OF PRESENT POLICY

There are at least four major reasons why changes in existing policy or adoption of a new policy should be considered. These are: 1) the results of reassessment of the hazards of biological contamination of celestial bodies by the scientific community, 2) the impact of planetary exploration during the 1970-1980 decade, 3) the obsolescence of mathematical models in deriving planetary protection constraints, particularly the use of P(g), and 4) consideration of the exploration rate and types of missions for the 1980's. Although these reasons are stated separately, all are in fact closely related and interdependent.

A. REASSESSMENT OF HAZARDS

The current policy was adopted at a time when the philosophy for approaches to planetary exploration was conservative. With the newly acquired capability of exploring the planets by remote probes, an historic opportunity had been made available to the biological sciences, that is: the opportunity to test fundamental questions about the origin and development of life in a planetary system (27). There was great concern by many ranking biologists that this unique scientific opportunity might be lost irretrievably if terrestrial microflora or organic materials were allowed to contaminate the planets. It was thought that this might occur by disruption of planetary ecologies through pathogenicity or competitive displacement, or by implanting terrestrial species that might adapt and proliferate in local ecologies thereby perpetually confusing later investigations (28).

Admittedly the probability was small that this kind of contamination would result in destruction of critical scientific information. However, it was felt that the great importance of the scientific rewards balanced a low probability of scientific loss (29).

This conservative position was prompted by the relatively limited knowledge of conditions on planetary bodies as well as uncertainties about the limits of adaptability of terrestrial microorganisms to environmental extremes different from those existing on Earth. Furthermore, there was not time prior to starting exploration to execute appropriate Earth-based biological research programs that would more precisely evaluate the true risks of damaging subsequent biological investigations of the planets. The pursuit of such projects would have delayed the exploration program for many years. It seemed necessary at the time to compensate for insufficient knowledge by adopting a highly conservative policy.

This philosophy has now changed due partly to findings of the planetary exploration program over the past ten years, recent reassessments by the Space Science Board Committee on Planetary Biology and Chemical Evolution, and the obvious need to relieve unnecessary burdens on flight projects whenever possible. Thus, there is a strong need to make the NASA planetary protection policy consistent with current knowledge and beliefs.

B. SUMMARY OF FINDINGS OF THE PLANETARY EXPLORATION PROGRAM RELEVANT TO PLANETARY PROTECTION

1. Mercury and the Moon

Surface conditions on Mercury and the Moon have many similarities with respect to temperature, atmosphere, thermal inertia, impact craters and radiation. Radiation fluxes on Mercury are higher than on the Moon, of course, due to its closeness to the Sun. Data from Mariner 10 significantly advanced the state of knowledge about Mercury, particularly with regard to surface characteristics, atmospheric composition, magnetic fields and optical and surface thermal properties (30).

Neither the Moon nor Mercury has ever been of great biological interest because of the lack of a significant atmosphere, high thermal fluxes and high ultra-violet radiation levels. The new data from Mariner 10 reaffirmed this conclusion for Mercury. At one time it was suggested that the moon might be a repository for past biotic or pre-biotic processes or it might provide an opportunity to test the panspermi hypothesis (31). But after several lunar projects including Ranger, Lunar Orbiter, Surveyor and finally Apollo, there now seems to be little hope that the Moon can provide any clues to solving fundamental biological problems, except perhaps by extensive sub-surface investigations. Thus, other than some care in preventing possible chemical contamination that might confound a subsequent planetary investigation there is no explicit planetary protection requirement for the Moon and no change is contemplated.

2. Venus

A wealth of new information has accumulated about Venus over the past ten years as a result of measurements taken with Earth-based instruments, fly-bys, orbiters and atmospheric/surface probes including Venera 5 through 12, Mariner 10 and Pioneer Venus 1 and 2. The information includes temperature profiles from the upper atmosphere to the surface, composition, structure and dynamics of the lower, middle and upper atmosphere, composition and distribution of cloud layers and surface properties.

Elevated temperatures at the planets' surface and in the lower atmosphere almost completely exclude the planet from being biologically interesting. A range of temperatures compatible with terrestrial biology occurs in the atmosphere between about 48 to 60 kilometers where pressures are 1.3 to 0.2 earth atmospheres (32).

Most of the main cloud deck is between these altitudes (33). Besides major components CO_2 and N_2(8), the atmosphere contains aerosol fractions believed to be mostly sulfuric acid droplets with other as yet undefined phases (33). The abundance of measured water vapor is consistent with that in equilibrium with approximately 85 percent sulfuric acid solution (34). Conceivably, sulfuric acid is a sink for atmospheric water.

The current value of P(g) for the Venusian atmosphere (which predates the exploratory missions discussed above) allows for the remote possibility of growth of terrestrial microorganisms. However, the latest data suggest that the possibility of growth of terrestrial microorganisms in Venusian clouds is perhaps even more remote than previously estimated. Only highly specialized, and no doubt rare, species could possibly adapt to an environment where it would grow in aerosols, be unaffected by, or perhaps utilize high sulfate concentrations at a very low pH, and grow at low water activities. The possibility of finding such an organism on Earth, collecting it on a spacecraft and transporting a sufficiently large population to successfully innoculate the Venus atmosphere seems extremely remote, indeed. A review of the planetary protection requirements for the atmosphere of Venus by the SSB is needed because the body of more recent information would be expected to reduce the requirements for the atmosphere to a level comparable to those for the surface of the planet.

3. Mars

Viking results especially related to biological questions and planetary protection include those from global surface temperature measurements, atmospheric water vapor determinations, observations of hydrologic surface formations, atmospheric composition, analysis of surface material for organic chemicals, and attempts to directly detect life.

Kieffer et al. (35) performed extensive global thermal mapping studies of the Martian surface. Surface temperatures of 130 to 290 K are reported. No local hot spots, such as those produced by active volcanism were observed.

A detailed model of the dynamics of global atmospheric water distribution was developed by Farmer et al. (36). Water vapor appears to be in equilibrium with subsurface ice residing at depths of 0.1 to 1 meter and at latitudes greater than about 46° north and 35° south. Because of low surface temperatures the vapor level is small, the maximum observed being only 100 micrometers of precipitable water.

Considerable evidence for water-ice at the surface and in the subsurface was obtained. Besides the implications of seasonal variations of atmospheric water vapor just mentioned, an extensive array of hydrological surface formations were observed, ranging from various types of surface disruptions to large channels with apparent fluvial patterns (37). The release of 0.1 to 1% water upon pyrolysis of soil samples (38) also indicated the presence of crystalline bound surface water. No liquid water was detected, and was not expected due to the extremely low temperatures and pressures.

Constituents of the atmosphere of biological interest were determined both by mass spectroscopy (39) and gas chromatography (40), both analyses being in good agreement. Nitrogen was of particular biological interest because the existence of life depends on its availability. The analyses gave: carbon dioxide 95.32%, nitrogen 2.7%, oxygen 0.13%, carbon monoxide 0.07% and water vapor approximately 0.03%.

Surface samples collected from different locations surrounding the Viking landers were analyzed for the presence of organic compounds by pyrolysis-gas chromatography-mass spectrometry (38). Although maximum sensitivity of the system was about 1 part per billion, no indigenous organic matter was detected.

Two of the three life detection experiments yielded responses that were considered consistent with biological activity. The third experiment (40), designed to measure the biological gas exchange of soil microorganisms, detected a burst of molecular oxygen when a soil sample was exposed to an atmosphere saturated with water vapor at approximately 15°C. The amount of oxygen released was considerably greater than could be expected from simple desorption of atmospheric gas. The decomposition of an oxygen containing compound seemed more likely. From this result it was hypothesized that a strong oxidizing agent existed in the surface material, presumably a peroxide or superoxide. The hypothesis was, of course, consistent with the absence of organic matter.

Of the two experiments that obtained positive results, one was designed to detect biological oxidation of added organic compounds (41) while the other detected reduction of carbon dioxide or carbon monoxide by soil organisms (42).

Due to the apparent existence of a strong oxidant, and the absence of organic material in the surface, the results of the life detection experiments were considered to have been induced by chemical rather than biological processes (43).

The results summarized above were those mainly considered by the Space Science Board in recommending new values of P(g) for Mars (44). The surface temperature distribution, the absence of liquid water, the absence of organics and the inferred presence of a strong oxidant in the soil led to a reduction in P(g). A new policy should contain requirements that are consistent with those recommendations.

4. The Outer Planets and Their Satellites

The outer planets are Jupiter, Saturn, Uranus, Neptune and Pluto. Other than Titan none of the satellites of the outer planets are of particular biological interest. The planets themselves, however, are interesting because of detectable amounts of organic compounds in their atmospheres.

The Committee on Planetary Biology and Chemical Evolution has performed a careful analysis of the possibility of a terrestrial organism growing in any of the outer planet environments (44). Their conclusion was that the chance is nil. This determination was based on models of the atmospheres of Jupiter, Saturn, Uranus and Neptune developed by Weidenschilling and Lewis (45) and an assessment of microbial growth under the most favorable conditions predicted by these models.

This study was performed three to four years prior to the encounters of the Pioneer and Voyager spacecraft with Jupiter and Saturn. Although no new data affecting biological interest in Jupiter or Saturn was obtained by these missions, new information on the atmosphere and temperatures of Titan significantly affects the assessment of its planetary protection requirements. The data consists of IR spectra showing the presence of hydrogen cyanide (46) which had not been shown previously, a predominately nitrogen atmosphere (47), (48) with a surface pressure of 1.6 bars and a temperature of 93 K, (-180°C)

(48). These low temperatures render the possibility nil for the growth of terrestrial organisms on Titan.

C. MATHEMATICAL MODELS

It was stated previously that NASA is committed to conduct a planetary protection program that limits contaminating a planet or satellite of biological interest to a probability of 1 chance in 1000. To meet this requirement a mathematical model was established that included various probability parameters associated with events or conditions affecting the deposition and establishment of terrestrial microbes on a target body. This model is no longer useful or desirable because of reassessments of the danger of contaminating planetary bodies and because of inherent weaknesses of the model itself. The main weakness is the large uncertainty in assigning values to the parameters, while the reassessments have resulted in recommendations for P(g) values low enough to make planetary protection constraints unnecessary for most missions.

The uncertainties in assigning values to the parameters of the model have been particularly troublesome in the case of P(g) because its value can be assigned with much less certainty than the other parameters, yet it dominates the others in determining a value for the probability of contamination P_c. Assigning values to the parameter P(g) was never popular with NASA's scientific advisors, and these exercises tended to be carried out as a concession to project engineers for designing missions and meeting quantitative requirements. Although the most serious objection is the assignment of P(g), the values of some of the other parameters used in the probability model also have a limited experimental basis.

The Space Science Board's Committee on Planetary Biology and Chemical Evolution strongly condemned the probability approach, particularly the use of P(g), for establishing planetary protection restrictions for each mission (44). In their view, "The assignment of numerical probabilities to phenomena that are qualitatively unknown is inappropriate. There is limited value in the assignment of a probability between 0.0 and 1.0 of growth of a microorganism when nothing is known about the identification and metabolic capabilities of the organism, the size of the initial inoculum, the presence of associated microorganisms, the details of the environment in question, and most important the detailed changes in all of the relevant environmental factors with time." They recommended an alternative approach be developed preferably based on experimental data rather than generalized guesses.

Although the assignment of numerical values to P(g) is uncertain, the trends if not the absolute values do reflect the degree of concern for the protection of the various planets. Since the Space Science Board is well aware of the application of their recommendations for values of P(g) to the mathematical model, one may review the implications of its latest recommendations in this regard. It seems clear that the Board and other scientific advisors would prefer to recommend requirements for various planets rather than values for P(g). Nevertheless, the most recently recommended values for P(g) for Mars and the outer planets and satellites (44) are shown in Table 2, along with earlier estimates (49) for Mercury and Venus.

The need for "active planetary protection (PP) methods", such as terminal heat treatment to reduce bioloads, or less active "clean assembly", was estimated using the current mathematical model and typical spacecraft bioburdens and allocations (e.g. for Viking and Voyager). These considerations indicate that active methods would be required for missions to planets with assigned values greater than or equal to 10^{-9} for P(g). Missions to planets with smaller P(g) values generally require clean assembly. However for an assignment of either a nil P(g) or a value less than 10^{-14}, no planetary protection implementation is required.

The numerical value, less than 10^{-14}, was proposed by the SSB for the outer planets and their satellites only for satisfying NASA's commitment to a mathematical demonstration of compliance with mission allocations. When the value 10^{-14} is used for P(g) in the equation for determining P_c, none of the allocations currently existing would be exceeded, even by spacecraft with microbial burdens two orders of magnitude higher than typical burdens.

Table 2. Existing and Recently Recommended Values of P(g)

BODY	P(g) VALUE	NEED FOR ACTIVE P.P. IMPLEMENTATION [a]
Mercury	Nil	None
Venus	Nil Surface	None
	10^{-9} Atmosphere	Active P.P. Methods
Mars	10^{-7} Residual Polar Caps	Active P.P. Methods
	10^{-8} Subsurface (sub-polar)	Active P.P. Methods
	10^{-10} Surface to 6 cm (sub-polar)	Clean Assembly
Jupiter	$<10^{-14}$	None
Saturn	$<10^{-14}$	None
Uranus	$<10^{-14}$	None
Neptune	$<10^{-14}$	None
Moon	Nil	None
Satellites of the outer planets	$<10^{-14}$	None
Titan	10^{-10}	Clean Assembly

[a] Based on estimates from previous missions.

The important implications of these assignments to P(g) under present planetary protection policy are that only Mars, and possibly Venus, require active bioburden reduction methods, the other planets and satellites requiring at most clean room assembly. The second result is that the frequent assignment of less than 10^{-14} for P(g) reduces the need for a mathematical model since this eliminates planetary protection analysis for missions to those planets.

Both the Space Science Board and COSPAR have recommended that spacecraft for missions to the outer planets be assembled under clean room conditions comparable to the Viking Project (44,50). With a generalization from outer planets to all planets with very small P(g) values (i.e. nil) except those declared to be of no biological interest (e.g., Mercury), this recommendation introduces the concept of a minimum, or baseline, planetary protection requirement. The intent of this recommendation was an effective requirement that imposed no unreasonable constraints on the conduct of a planetary mission and in fact would be beneficial to spacecraft system and science instrument reliability. While the concept is useful, the reasonableness of the particular requirement is arguable. Moreover, the reliability issue is not a Planetary Protection Program matter. (See also the Appendix, "Science Instruments and Planetary Protection Policy".)

This recommendation is an example of translating expert scientific judgement on planetary protection requirements directly into practical operational procedures without cloaking the judgement in a semi-quantitative form. This approach can also be used in defining planetary protection requirements for Mars or other bodies requiring more stringent precautions. It would avoid the bothersome problem of assigning a numerical value to the parameter P(g).

D. EFFECT OF MISSION MODELS

At the time the present policy was initiated major consideration was being given to the exploration of Mars, primarily because it has an environment apparently less hostile to the development of life than any other planet. Much of the thinking about planetary protection was done with emphasis on Mars for that reason. Although Mars is still of major interest, current mission models postpone further exploration of it until the 1990's. Earlier missions are to targets that should have minimal or no planetary protection constraints. Although in principle policy should be independent of any mission model, in practice the policy should at least be consistent with plans for future missions. As mentioned earlier, the policy should treat Mars or other planets of biological interest as exceptions and provide that all other missions should have only minimal or no planetary protection constraints.

To summarize, the current policy requirements are no longer realistic. The considerations and scientific rationale leading to the establishment of the current policy were probably overcautious, in retrospect. There has been an enormous advance in our knowledge of the planets in the past 10 years, and some of it has resulted in revised opinions about the risk of contamination to future scientific missions. This is reflected in the latest recommended P(g) values for Mars and the outer planets, the latter having been lowered to extremely small values, actually nil, by the SSB. The new values of P(g) and the obvious unreality of determining the real value of parameters, especially P(g), in the mathematical model used in planetary protection, emphasize the need for a more realistic approach. As a minimum a new policy should deemphasize the mathematical approach by translating scientific judgements directly into operational procedures and methods and should adopt suitable planetary protection requirements for all missions to planets of biological interest. Missions to Mars (and possibly Venus) that require active planetary protection procedures should be treated as exceptions. Finally, the current rate of planetary launches and the inflexibility of the current policy also requires an improved, more liberal policy.

SECTION III

THE PROPOSED POLICY

The proposed policy, like the current policy, addresses NASA concerns for the preservation of "planetary conditions for future biological and organic constituent exploration" (22) and for the protection against the "potential hazards to Earth of future returning missions". (19). The principal revision of the proposed policy is the elimination of the quantitative aspect of the current policy, i.e.: "The basic probability of one in one thousand ($1x10^{-3}$) that a planet of biological interest will be contaminated shall be used as the guiding criterion during the period of biological exploration..."(22). In view of this desired change and the necessity of the change as presented in the previous section, the proposed basic policy might be expressed in the following manner:

> Although the existence of life elsewhere in the solar system may be unlikely, the conduct of scientific investigations of possible extraterrestrial life forms, precursors and remnants must not be jeopardized. In addition the Earth must be protected from the potential hazard posed by extraterrestrial matter carried by a spacecraft returning from another planet. Therefore, for certain space mission/target planet combinations, controls on contamination shall be imposed, in accordance with issuances implementing this policy.

In addition to the elimination of the quantitative aspect of the current policy, the proposed policy establishes two new major features by the phrase "certain space mission/target planet combinations." The intentional use of the word "certain" denotes that most space missions will be relieved of all planetary protection requirements. That is, as a matter of policy, implementation will be accomplished on a "by exception" basis. Secondly, the identification of those exceptional missions and the requirements imposed will be based both on the target planet and the type of encounter (fly-by, orbiter, probe, lander, etc.). For planetary protection purposes, the term "planet" includes the major planets, planet satellites, as well as other solar system bodies, i.e. comets, asteroids, etc.

The proposed policy thus seeks to incorporate the essentially negative findings on the existence of life in the solar system and to recognize that the planetary exploration program is quite limited, in a prudent manner. The concepts of mission/planet combinations and of implementation by exception are the mechanisms proposed. The qualitative nature of the proposed policy remedies the inherent difficulties in the determination of a probability of contamination based significantly on the probability of growth, to the greatest extent feasible.

The proposed policy and these major features are reflected in significant changes in the implementation and requirements of Planetary Protection. This matter will be developed further below.

A. DETAILS OF THE PROPOSED POLICY

A principal revision in the implementation under the proposed policy is the introduction of categories of mission type/planet combinations. These categories are similar to the mission classes of NHB 8020.12A(24). However, there are now gradations of biological interest which are assigned to the planets. Active biological interest denotes a declaration by the scientific community that a specific planet may possess indigenous life forms, precursors or remnants. Minimal biological interest allows for possible precursors or remnants but denies the existence of indigenous life forms. No biological interest denies the existence of all of these factors.

The basis for the logical construction of the categories follows from the goals of the basic policy: the protection of the Earth from extraterrestrial contamination and the protection of future life science at target planets. All Earth return missions (those involving direct contact with extraterrestrial planets followed by return of spacecraft hardware to the terrestrial system) are placed in category V. Here the implementation and requirements are most stringent, reflecting a high degree of concern. The degree of concern for the protection of future life science at a target planet is based on the biological interest in the planet, on the encounter type of the mission, and the likelihood of a putative contamination event. All missions other than Earth return missions are placed in categories for increasing degree of concern (I through IV).

Category I essentially corresponds to the present class 1, i.e. any type of mission to a target planet of no biological interest. In effect no protection of such planets is warranted.

Category II missions comprise all types of missions to those target planets for which there is minimal biological interest <u>and</u> an opinion among the scientific community that there is a remote chance of contamination carried by a spacecraft or associated hardware jeopardizing a future biological experiment. In this context, contamination means the introduction of terrestrial life forms, remnants or organic constituents on or in a spacecraft or on an extraterrestrial planet. Biological experiment includes any of which the stated or prudently interpreted objective is the investigation of extraterrestrial life forms, precursors or remnants (i.e. includes both life detection and organic constituent investigations). Category II represents those missions for which the need for planetary protection cannot be totally discounted.

Category III missions comprise some missions to a target planet of biological interest <u>or</u> for which scientific opinion provides a significant chance of contamination jeopardizing a future biological experiments. Category III is limited to such missions where no direct contact (spacecraft hardware contact with the body or permanent atmosphere) with the target planet at issue is intended or planned. Thus the encounter types include fly-by and orbiter (if the final planned disposition of the orbiter is to avoid or prevent impact with the target planet).

Category IV missions comprise some missions to a target planet of biological interest <u>or</u> for which scientific opinion provides a significant chance of contamination jeopardizing future biological experiments. Category IV is the subset of such missions where direct contact with the target planet at issue is intended. Thus the encounter types include probe, lander and orbiter (if the final planned disposition of the orbiter is to allow an impact with the target planet).

Category V missions comprise all Earth return missions, as previously stated. For the set of target planets deemed by the scientific community to have no indigenous life forms a special subcategory "safe for Earth return" would be defined. An existing example is a lunar sample return mission. Note that this is a logically less severe restriction than a declaration of no biological interest. However, it is expected that the former conclusion will be approached much more conservatively. Missions that are Earth return and directly contact only planets declared "safe for Earth return" would be placed in this subcategory.

The logic diagram for the determination of the category of a specific mission type/target planet combination is shown in Figure 4. For multiple target planet missions, the correct category is the highest possible, considering the various planets involved. Of course the detailed implementation requirements will be relaxed at the lower priority targets. In order to explicitly determine the category of a particular mission, the planetary protection priority (i.e. the level of biological interest) of all its target planets, as well as its type, is required. The definition of these priorities and a proposed assignment of all planets is provided in Table 3.

Priority A comprises the Sun, Moon, Mercury and Pluto. These celestial bodies have been determined to have no biopotential and hence are of no biological interest. Priority B contains the outer planets (except Pluto) and their satellites, comets and asteroids. Special attention is drawn to inclusion of Venus and Titan into this priority. The probability of growth for the atmosphere of Venus has been assigned since 1973 a value of 10^{-9} which can be interpreted as a minimal degree of interest. At the same time the surface of the planet has been declared of no biological interest by the assignment of a nil value. A reassessment, as recommended in an earlier part of this report, of the atmosphere of Venus may remove Venus to priority A. Titan has been assigned a probability of growth value of 10^{-10}, again reflecting minimal biological interest. As presented previously in this report, the recent Voyager findings on the surface temperature of Titan support an assignment of minimal interest (only). Accordingly priority B is recommended here. The proposed priority of comets and asteroids is not based on the published probabilities of growth; there are none. The priority B

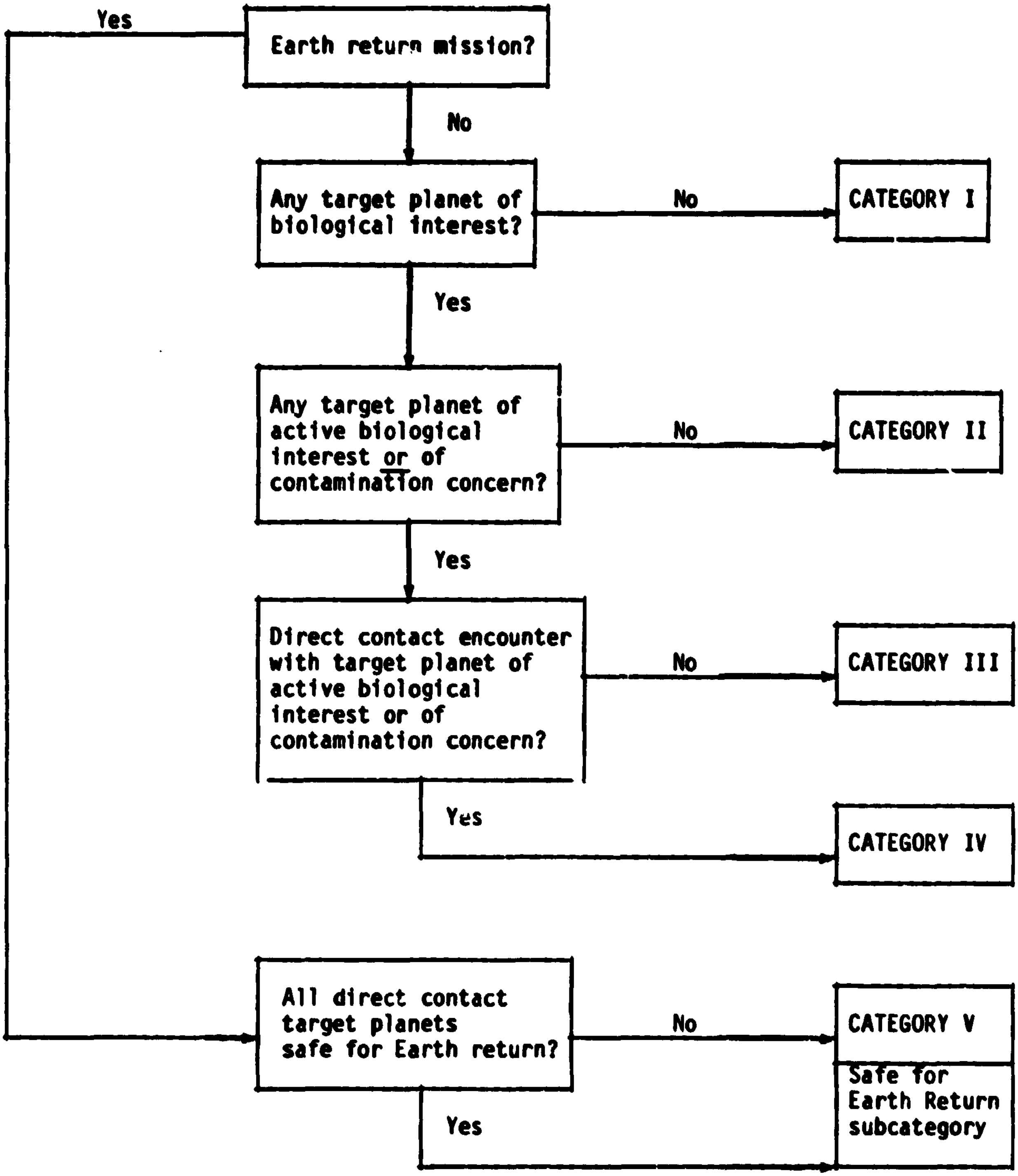


Figure 4. Logic for the Determination of Mission Category

Table 3. Planetary Protection Priorities of Target Planets

PRIORITY	DEFINITION	EXAMPLE TARGETS
A	No biological interest	Sun, Moon, Mercury, Pluto
B	Minimal biological interest <u>and</u> minimal contamination concern	Venus, Jupiter, Saturn, Uranus, Neptune, outer planet satellites, comets, asteroids and others
C	Active biological interest <u>or</u> significant contamination concern	Mars

assignment is consistent with the possible existence of life precursors (of special interest for Comets) and life form remnants, but disclaims the existence of indigenous life forms. (See, e.g. Ref. 51.) Finally, Mars has been singled out by the scientific community and NASA's advisory groups as a planet of active biological interest, both in terms of possible indigenous life and life-related molecules. Thus Mars is placed in priority C.

The proposed prioritization of target planets according to biological interest and contamination concern is based on best available scientific judgement. However, there are several possible circumstances which would require a review and reconsideration of the priority of a planet (in addition to any regular review process). Such occurrences relative to a target planet include but are not limited to: increased possibility of the existence of life forms; the approval for flight of a biological experiment of the life detection type; the approval for flight of a biological experiment of the organic constituent, precursor or remnant type; and the subsequent discovery of life forms, precursors, or remnants.

The preceding development may be summarized as shown in Table 4. Also indicated is a general statement of the degree of concern and an indication of the general range of requirements for each category. These considerations will be discussed below.

The general rationale, which derives from the proposed policy, is to impose an increasingly stringent set of requirements on spacecraft mission/planet combinations which represent an increasing threat to further scientific investigations of possible life forms, precursors or remnants. This factor is reflected in Categories I through IV. The principal concern for Earth return missions, Category V, is the protection of the terrestrial system. This concern also follows directly from the proposed policy.

Therefore, since Category I consists of missions to planets of no biological interest, there are no requirements at all. It will be necessary, however, that a flight project submit a letter to the Chief, Planetary Protection Program (CPPP) requesting a Category I classification based on the mission's intended and unintended targets. In the case of Category II missions the priority of the planets and the type of missions imply only a minimal degree of concern. The interest is only in terms of life-related molecules (i.e. organics). Hence accidental impacts should be avoided, and some effort expended to limit contamination for a direct contact mission. However, the requirements are for simple documentation only. Flight projects will have to prepare a short PP Plan primarily to outline intended or potential impact targets, brief pre-and post-launch analyses detailing impact strategies, and a post encounter or end-of-mission report whicn will provide the location of impact if it occurs. The main protection of future science will in fact be the record of Category II missions, especially the final actual disposition of the hardware as reported in the End of Mission Report.

Significant biological interest or serious contamination concern evidenced by the target planet priority and a non-direct contact flight plan characterize Category III. The concern in this case is manifested in a specified upper limit on the probability of impact and a requirement for some contamination control. In practice some trade-off between probability of impact and classes of contamination control procedures would be established in the Planetary Protection Plan for a specific Category III spacecraft program.

Compliance on the part of projects will depend on the type and specifics of the missions. For a fly-by, compliance may be limited to a detailed analysis showing that the probability of impact is below the stated limit (which may require trajectory biasing). It is not expected that fly-by missions will have bioload requirements. For orbiter type misions, the "avoidance of impact" requirement may be levied in the form of an orbital lifetime. In this instance, compliance by a project will include analysis of the expected orbits to show that they can be maintained for the period of the assigned lifetime. Bioload requirements may be levied on orbiters both to prevent excessive ejecta efflux and to limit the contamination potential in the event of an unexpected orbit decay. If such requirements are imposed, they will call for the use of clean room technology but they will not require a bioassay. Project compliance will necessitate an accurate description and assessment of the clean room facilities used and the procedures employed.

The types of requirements imposed on Category III missions will consist of more involved documentation (than Category II) and some implementing procedures, such as trajectory biasing, clean rooms and occasionally bioburden reduction. The nature of the contamination control will typically be passive. That is, the cleanliness of the spacecraft will be inferred from a knowledge of the efficacy of the standard procedures and methods employed and from prior facility verification (i.e. indirect measurements). The procedures and facilities and the analytical method for the inference of cleanliness will be detailed in the Planetary Protection Plan for the mission. Bioburden reduction techniques will be used only in the observed occurrence of anomalous (unplanned) contaminating events such as a clean room filter failure or a gross violation of personal procedures (i.e., in an emergency). Even in that case, the final burden will be estimated rather than directly measured (i.e., no bioassay will be performed). Although no impact is intended for Category III missions, an organics inventory will be required in the End of Mission Report only if an impact occurs. This inventory will include a list of bulk organic constituents of the spacecraft hardware and their mass. It will not include materials in small quantities or the minute amounts of surface contaminants on the hardware. There will be no requirement to maintain samples of any organic materials.

Table 4. Proposed Categories for Planets and Types of Missions

	CATEGORY I	CATEGORY II	CATEGORY III	CATEGORY IV	CATEGORY V
			No Direct Contact	Direct Contact	
Type of Mission	Any but Earth Return	Any but Earth Return	(flyby, some orbiters)	(lander, probe, some orbiters)	Earth Return
Target Planet	Priority A Sun Mercury Pluto	Priority B Venus, Jupiter, Saturn, Outer planet satellites Uranus, Neptune, Comets, Asteroids, Others	Priority C Mars	Priority C Mars	Any
Degree of Concern	None	Record of planned impact probability and contamination control measures	Limit on impact probability Passive bioload control	Limit on probability of non-nominal impact Limit on bioload (active control)	If <u>not</u> Safe for Earth Return: No impact of Earth or Moon Sterilization of returned hardware Containment of any sample
Representative Range of Requirements	None	- Documentation only • PP plan (brief) • Pre-launch report (very brief) • Post-launch report (very brief) • Post encounter report (very brief) • End of mission report (brief)	- Documentation (more involved than Category II) • Contamination control • Organics inventory (as necessary) - Implementing procedures such as: • trajectory biasing • cleanroom • bioload reduction (as necessary)	- Detailed documentation (substantially more involved than Category III) • P_c analysis plan • Microbial reduction plan • Microbiological assay plan • Organics inventory - Implementing procedures such as: • trajectory biasing • cleanroom • bioload reduction • partial sterilization of contacting hardware (as necessary) • bioshield - Monitoring of bioload via bioassay	<u>Outbound</u> - Per category of target planet/outbound mission <u>Inbound</u> If <u>not</u> Safe for Earth Return: - All of Category IV - Continual monitoring of project activities - Pre-project advanced studies/research If Safe for Earth Return: None

Category IV missions, as defined, pose the greatest threat to further scientific investigation of extraterrestrial life forms, precursors and remnants. While Category III missions are to the planets of greatest biological interest, the Category IV flight plan additionally calls for direct contact. Thus planetary protection concerns cannot be met by the avoidance of impact. Generally Category IV missions must control the bioburden on all hardware which is intended to directly contact the target planet and must meet limits on the probability of non-nominal impact. Here non-nominal impact includes both accidental impact by hardware not planned for direct contact and a significant deviation from plan by the direct contact intended hardware. The type of requirements imposed include rather detailed documentation (more involved than Category III), an increased number of implementing procedures, a bioassay to enumerate the bioburden and a probability of contamination analysis. The implementing procedures required would include trajectory biasing, clean rooms, bioload reduction, possibly partial sterilization of the direct contact hardware and a bioshield for that hardware. Generally the requirements and compliance will be similar to Viking, with the likely exception of complete lander/probe sterilization.

To comply with the requirement of no accidental impact the project will have to present analyses showing that for the selected trajectory(ies) the corresponding probability(ies) of impact are within what the requirement will term "acceptable" levels. This may require trajectory biasing. To comply with the requirements referring to control of bioload, the project will have to utilize clean rooms and attendant procedures and demonstrate their effectiveness through a series of independently taken bioassays. An upper limit on bioload will be imposed which the project cannot exceed. If partial sterilization (dry heat) is required, the project will have to provide the facility and means to accomplish it. The facility will be subject to certification and the means of sterilization (time-temperature-humidity regimes) subject to approval and monitoring. Following bioload reduction and partial sterilization (if the latter is required), the project will have to demonstrate that the spacecraft (lander or probe) is adequately protected against recontamination, particularly in the STS facilities. This may require the use of a bioshield or shroud. Whatever the means of protection, the project should provide for their continuous monitoring through launch. The accounting for bulk constituent organics will involve the inventory referred to under Category III, but it will be required as part of the Pre-Launch Report.

The concern for Category V missions is the protection of the terrestrial system, the Earth and the Moon. (The Moon must be protected from back contamination to retain freedom from PP requirements on Earth-Moon travel.) However, for the special subcategory, "safe for Earth return", there is no need for any protection, by definition. Missions in this subcategory will have PP requirements on the outbound phase only, corresponding to the category of that phase (typically Category I or II). Such flight projects will have to formally request this categorization from the CPPP. For all other Category V missions, the highest degree of concern is expressed by the absolute prohibition of impact, the need for sterilization of returned hardware which directly contacted the target planet, and the need for containment of any unsterilized sample taken there and returned to Earth. In general this concern is reflected in a range of requirements that encompass those of Category IV plus a continuing monitoring of project activities and pre-project studies and research (e.g., in remote sterilization procedures and containment techniques). The requirements for the protection of Earth have been and continue to be the subject of a number of studies which will eventually lead to their detailed definition. Those requirements will affect all phases of the mission, namely the outbound leg, the sample acquisition, transfer, and storage, the sealing of the sample container, the monitoring of the sample, the return phase of the mission, the Earth entry phase and the sample receiving laboratory. However, an Earth return mission must be viewed as a multitarget mission. The target planet must also be protected, insofar as this does not increase the risk to Earth. As such, the relevant parts of the documentation and the implementing procedures for the outbound phase of the mission must meet or exceed the requirements of the category appropriate if there were no return phase.

B. IMPLEMENTATION AND METHODS OF COMPLIANCE

The two major changes introduced by the new planetary protection (PP) policy are the shift from a quantitative top level statement and the imposition of requirements by exception rather than rule. These changes will impact considerably on the implementation as it will be defined in subsequent documents, the most important being a revised version of the NHB 8020.12A (24) type issuance. There will be no attempt at this time to detail the implementation of the new PP policy. This will be accomplished later in the course of revising existing implementing issuances. The purpose here is to outline main changes in the implementing procedures and methods of compliance, make preliminary assessments of the generic impact of those changes on future flight projects and highlight other changes which may be warranted in subordinate implementing issuances. The implementation of the existing policy as defined in NHB 8020.12A (24) establishes PP requirements by mission class without any regard to the target planet (except for the Sun and Mercury which are defined as being of no biological interest). This approach results in both generic and baseline requirements for any given class of missions reflecting, of course, the intent of the existing policy. How much more stringent than the baseline the generic requirements are depends on the probability of growth for the target planet.

The implementation of the new policy will adopt a more direct, yet less generic means of levying requirements. It will be more direct because instead of establishing requirements by mission class it will do so by target planet/mission class combinations. This will remove the element of uncertainty about the extent and severity of PP requirements for any one mission. It will be less generic because it will utilize more specific and more numerous categories, via the scheme of target planet/mission class combinations, than existing implementation. There will be no baseline requirements across categories in terms of either documentation or hardware requirements. Additionally, because the new policy no longer is quantitative, there will be categories of planet/missions with no quantitative requirements. This will eliminate for those categories the need for analyses and related documentation. Quantitative requirements under the new implementation will be levied exceptionally on those planet/mission combinations which warrant them.

It is anticipated that those quantitative requirements will be different from the ones imposed by the existing implementation. The latter have evolved from the quantitative policy they implemented and were designed to serve probabilistic models which were the keystone of PP analyses. It is not certain at this time how much the new implementation will deviate from the probabilistic approach. It is, however, safe to assume that different (and mostly operational) implementing procedures will be adopted. The emphasis will be on specific requirements developed for specific planet mission combinations; these requirements, particularly the quantitative in nature, will be so designed as to minimize the need for the type of analysis which employs parameters whose values can only reflect our uncertainty about them. This change in emphasis will undoubtedly affect existing subordinate implementing issuances, most particularly the Parameter Specification Book (49). It is anticipated that some of the existing parameters will be deleted or replaced by a series of quantitative requirements most of which will be expressed in terms of "hard" values rather than uncertain probability numbers. This will require extensive study and careful analysis and will be a major part of the Phase II effort. (Set to begin on October 1, 1981 and to be completed a year later, this activity will accomplish the revision of all implementing issuances.)

It was stated above that the quantitative requirements will be imposed exceptionally on planet/mission combinations which warrant them. Specifically, given the state of knowledge to date and the latest SSB recommendations, it is anticipated that only the combinations involving Mars and Earth will be the exceptions. For Mars and the Earth the combinations will involve all types of missions (with reduced emphasis for a Mars flyby). It follows then, that for all other planets there will be no quantitative requirements. In fact, it is anticipated that for most of the combinations involving planets other than Mars and Earth there will be no PP requirements at all. This will result in less cumbersome, more direct and more explicit implementing issuances.

From the standpoint of future flight projects, the new policy and its implementation will offer great benefits. Most flight projects will be in Categories I and II (to planets other than Mars and Earth return) where the effect will be almost total relief from any and all requirements. Even in cases where some documentation requirements may be necessary (Category II), they will be far less than what the existing implementation requires. For missions to Mars and Earth return (Categories III, IV and V), the requirements will be less elaborate, more specific and more in line with the current state of knowledge. Extensive documentation requirements will be alleviated and overall compliance by projects will be both simpler and more easily monitored and verified.

For NASA's advisory bodies, particularly SSB, the new policy and implementation will prove responsive to their recommendations to date and will provide them with a mechanism for a more meaningful, specific input to NASA. Specifically, when SSB is asked to express a degree of concern about a planetary body, it will be expressed in terms of real and specific constraints on missions rather than in terms of an uncertain probability of growth value. This will allow NASA's advisory bodies to become an integral part of the establishment and review of PP requirements. Examples of this participation will include the review of the proposed prioritization of the target planets and the establishment of the formal assignments and the determination of the target planets that are safe for Earth return.

In summary, the aim of the new implementing procedures will be to drastically reduce generic requirements, to remove uncertainties from the quantitative requirements, and to facilitate compliance and verification. As in the case with the existing implementation procedures, a revised version of NHB 8020.12A (24) will be the governing document. It will include the same chapters as the existing document, namely Introduction, Requirements, NASA Constraints, Management, and Glossary. In addition to the differences from the existing version which were described in this report, the revised handbook will further deviate from its predecessor document in that it will include top level requirements for missions returning to Earth.

Most of the quantitative requirements will be included in subordinate documentation referenced in the handbook. These requirements will be subject to periodic review to assure their compatibility with the ever changing state of knowledge.

C. ROLES AND RESPONSIBILITIES

An important integral part of a policy document is the establishment of roles and responsibilities for the administration of the policy and the development of amplifications and guidelines. The existing policy documents assign this responsibility to the Associate Administrator for Space Science. It is he who provides the funding for the administration of the Planetary Protection (PP) Program in NASA Headquarters delegating the responsibility for that program to the PP Officer.

The roles and responsibilities assigned to the Associate Administrator for Space Science, and through him to the PP Officer, by the existing policy documents include:

(1) Developing NASA basic policy and amplifications thereof for each target planet and the Moon.

(2) Prescribing regulations, standards, procedures and guidelines applicable to all NASA organizations, programs and activities to achieve the policy objectives.

(3) Certifying to the Administrator prior to launch that each space flight for the exploration of a planet or its satellite meets the requirements necessary to achieve the policy objectives.

(4) Conducting reviews, inspections, and evaluations of plans, facilities, equipment, personnel, procedures and practices of NASA organizational elements and NASA contractors to discharge the requirements of the Policy Directive.

(5) Taking actions as necessary to achieve conformance with applicable policies, regulations and procedures.

(6) Funding supporting research and technology required to implement the PP program.

(7) Representing NASA in PP technical consultations with other nations and international bodies such as COSPAR in coordination with the Assistant Administrator for International Affairs.

The new policy documents should assign similar responsibilities to the Associate Administrator for Space Science and the PP Officer. Further, they should explicitly state that those roles and responsibilities are delegated directly by the Associate Administrator to the PP Officer regardless of the division within NASA where the PP Officer resides. This has been historically the case in order to afford the PP Program and the PP Officer a degree of autonomy from any one NASA division, and authority over individual flight programs. Autonomy from NASA divisions allows the PP Program to be responsive to the needs of the agency and the agency's policy without being compromised by the narrower charter of the division under which the program operates. Authority over flight programs provides the PP Officer with the necessary leverage required to assure compliance on the part of individual programs and program managers.

Whatever the new policy and its implementation, the roles and responsibilities should be as clear and direct as they are under the existing policy, and should strive to ensure that NASA's PP Program is indeed a program of the agency and not of any of its parts.

D. INSTALLATION OF PROPOSED POLICY

The purpose of this report is to frame, detail and explain a new planetary protection (PP) policy for NASA. In the preceding sections the in-place PP policy was reviewed, a rationale for a new policy was developed, its features were analyzed and elements of its top level implementation were discussed. What this section will describe is how the overall report will lead to a formal new PP policy and what, if any, the implications and impact of this policy are on existing international treaties and agreements.

The existing PP policy is set forth in formal NASA policy documents, namely NPD 8020.7 (19) and NPD 8020.10A (22). These two documents define the PP policy and assign responsibility for its execution. They are relatively short documents signed by NASA's Administrator and/or Deputy Administrator. It follows then that the present report should eventually yield two new policy documents (NPD's 8020.7A and 8020.10B) which will replace NPD 8020.7 and NPD 8020.10A. The transition from the report to the policy documents will involve a series of reviews - informal and formal - by NASA's PP Program personnel, NASA's PP Officer, NASA's Director of Life Sciences, NASA's advisory groups and NASA centers. It is expected that the report on the new policy - which does include a policy statement - will first be reviewed by the PP Officer and the PP Program personnel. Following this review, it is anticipated that the edited report will be forwarded to NASA's Director of Life Sciences and the Space Science Board for their review and comments. This step may include brief presentations by the PP Officer and/or designated PP Program personnel. This series of reviews will result in a consensus position regarding the new PP policy. The consensus position will then be presented to NASA's Associate Administrator for Space Science whose comments should be solicited prior to the actual preparation of drafts of NPD's 8020.7A and 8020.10B. Preparation of these documents will then be a simple matter of stating and defining the agreed upon policy and assigning roles and responsibilities for its execution. Roles and responsibilities were addressed in a separate section of this report. When the draft policy documents are completed, the usual NASA review cycle for such documents will be followed. This includes review of the documents by NASA centers and the ultimate review and approval of NASA's Administrator or his designee.

Communication of the new NASA PP policy to the international community is presently set for the spring of 1982 during COSPAR's meeting in Ottawa, Canada. It is expected that the new NPD's will be in place by then, either as drafts undergoing final review or as formal NASA policy documents. In either case the new policy will be well formulated and its implementation outlined. From the work so far on the new PP policy and the direction being followed in its formulation and implementation some early assessments can be made of its impact on the International Treaty (20) and COSPAR requirements. Article IX of the International Space Treaty of 1967 (20), to which the U.S. is a party, states in part that

> "...parties to the Treaty shall pursue studies of outer space including the Moon and other celestial bodies, and conduct exploration of them so as to avoid their harmful contamination and also adverse changes in the environment of the Earth resulting from the introduction of extraterrestrial matter..."

The new policy will not violate this commitment. Where "harmful contamination" is possible, the new policy will provide for its prevention. The change from the old policy has to do with a redefinition of the need for protection. Whereas before it was generally assumed that most planetary bodies needed protection from terrestrial contamination, the new policy provides protection exceptionally to selected target planets which the current state of knowledge identifies as needing protection. Therefore, it can be concluded that the new policy will have little impact on the International Space Treaty (20).

However, both the treaty and basic COSPAR agreement (1966) (52) to which the U.S. is a party state that

> "...The basic probability of one in one thousand ($1x10^{-3}$) that a planet of interest will be contaminated shall be used as a criterion during the period of biological exploration..."

This top level quantitative guideline gave rise to the probabilistic approach adopted by the existing NASA policy and implemention. The new policy maintains strictly a qualitative posture without any quantitative guidelines at the policy level. This represents a deviation from the COSPAR requirement and will require proposing to the international body a resolution amending the quantitative guideline. Earlier sections of this report addressed the inherent disadvantages of such a top level guideline. We believe that COSPAR's intent- namely, the protection of planets of interest - can be served better without an artificial quantitative criterion which encourages demonstration of compliance via what has come to be known as the "numbers game".

Other COSPAR requirements which will be affected by the new policy and its implementation include the "Clean Room" resolution and the reporting requirements. The clean room resolution proposed in 1976 and adopted in 1977 recommends "the use of the best available clean room technology, comparable to that employed for the Viking missions, for all missions to the outer planets and their satellites (50). The new policy provides for no such blanket requirement. Indeed, for the outer planets and their satellites the new policy and its implementation will not include this requirement at all. A rationale will be presented to COSPAR for abandoning the clean room requirement.

The COSPAR reporting requirements call for annual submission of contamination logs for each of the target planets of exploration. Among the information included in the logs are estimates of the probability of contaminating the target planet, the spacecraft bioload at launch and relevant post-launch and post-encounter updates on missions. Depending on the details of the implementation of the new policy, some of the above data may have to be replaced by other types of information. Thus, while reporting regularly to COSPAR will continue, there may be changes in the form and type of information.

As the detailed implementation of the new PP policy develops the impact on COSPAR requirements will be better assessed, particularly as it affects reporting requirements.

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APPENDIX

IMPLICATIONS AND IMPACT OF THE PROPOSED POLICY

The major impact of the proposed planetary protection policy will be in the implementation and methods of compliance by future planetary missions. In fact, this effect is an objective of the policy revision. Therefore, an assessment of this impact and a discussion of the changes for specific planetary missions under consideration are in order. However, there are two other items of concern that both interact strongly with planetary protection policy and requirements. According to present NASA plans, all future planetary spacecraft will be launched by the Space Transportation System (STS). It is important to evaluate the proposed policy in light of this new launch system and operation and to compare it with the present policy in terms of its utility in meeting planetary protection needs in the Shuttle era. Finally, and perhaps most importantly, the issue of the relationship between the Planetary Protection Program and the scientific instruments flown on planetary spacecraft should be examined.

A. IMPLICATIONS AND IMPACT ON FUTURE PLANETARY EXPLORATION PROJECTS

As discussed in the main body of this report, the principal effect of the proposed policy is a significant reduction in the number and stringency of implementation procedures and activities required of planetary exploration missions. Although some of the details must await definition in the new implementing issues to be instituted after the acceptance and approval of the proposed policy, the general nature of the methods of compliance and requirements may be examined. The specific spaceflight missions reviewed in this subsection are: Galileo, a comet fly-by or encounter, International Solar Polar Mission (ISPM), Venus Orbiting Imaging Radar (VOIR), Saturn Orbiter with Two Probes (SOP2), and a Mars Surface Sample Return Mission (MSSR). This list of missions is not exhaustive of all possible planetary exploration missions, but all are either planned or fairly representative.

1. Galileo Project is a planetary exploration mission to Jupiter and its satellites consisting of a probe to Jupiter and an orbiter of the planet. According to the current mission plan, no other planets are involved. (A Mars gravitational assist had been planned in a previous version). It will also be one of the first planetary missions launched by the Space Transportation System. Under the existing policy, the Galileo Project is a Class 3 mission (Ref.A1) in that a probe to Jupiter is included. However, the Galileo Orbiter Project and the Galileo Probe Project intend to separately comply with PP requirements. Thus the Orbiter Project may be Class 2 or 3 in that NHB 8020.12A(Ref.A1) is not specific on planetary projects. The Probe Project is of course a planetary probe and, therefore, Class 3.

The general requirements for a Class 3 mission are "appropriate mathematical analyses and microbiological assay and control insuring that the mission probability of planetary contamination will not exceed its allocation. For some missions selected hardware may be subject to microbial reduction requirements" (Ref.A1). Also from NHB 8020.12A, for Class 2 missions only the analyses are required in all cases; microbiological assay and control may be needed.

Some specific PP requirements and specifications for the Jupiter Orbiter-Probe mission (as Galileo was formerly known) were set forth by the PP Program Office (Ref.A2). The mission probability of contamination allocation was fixed for Jupiter at 1×10^{-4} and for each of its satellites at 6.4×10^{-5}. The SSB recommendation for the probability of growth, P(g), for Jupiter and its satellites, 1×10^{-14} (Ref.A3), was adopted. A requirement "to utilize clean room technology similar to Viking (i.e., Class 100,000 clean rooms with appropriate procedures and controls)" was also imposed. This requirement was adopted from a 1976 COSPAR resolution (Ref.A4) and an SSB recommendation (Ref.A3). The issue of a formal orbital lifetime requirement for Jupiter and its satellites was resolved and eliminated somewhat later. However, the Galileo Project was required to avoid impact with Jupiter (by the Orbiter) and permitted to select a satellite for intentional impact to terminate the Orbiter's phase of the mission.

Given the small P(g) for Jupiter and its satellites, the standard probability of contamination analysis insures Galileo Project compliance with its allocations without any microbiological assay and with only Voyager-type contamination controls (Ref.A5) (i.e. including clean rooms operated at Class 100,000 and relaxed procedures and controls compared to Viking). This conclusion obtains even for a factor of fifty enhancement in microbial load over Voyager values, the assumed worst result of Shuttle launch facilities and standard operation (i.e. only controlled areas) (Ref.A6).[a] Accordingly the Project intends to use this standard analysis with a conservatively estimated microbial burden. No microbiological assay is planned.

The contamination control issue remains unresolved. The Galileo Project proposed a contamination control plan in outline form similar to that of the Voyager Project (Ref.A7) (Voyager's PP plan preceded the 1976 COSPAR resolution). This approach was generally accepted by the PP Program Office with a recommendation that the Project "analyze the STS situation and, to the extent possible, quantify the contamination that the STS environment would introduce to the spacecraft," as a prior condition to a discussion of the detailed contamination control requirements. (Ref. A8). Subsequently, some activity to obtain the needed data was initiated according to the KSC Facility Contamination Verification Test Plan (Ref.A9).[a] However, the work according to the plan was not completed.

From the preceeding review of the current state of planetary protection for the Galileo Project, it is apparent that the present policy permits considerable vagueness in the requirements, especially in those related to contamination control. Under the proposed policy, the issues of contamination control, category (class) of the mission, orbital lifetime, and final disposition of the Orbiter would not have arisen. The need for most of the dialog would be obviated by the clarification of the requirements. The specific requirements would also be significantly relaxed compared to the present situation.

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[a] See next subsection of this Appendix, "Planetary Protection for Space Transportation System Launches".

Under the proposed policy, Galileo Project would be a Category II mission. No contamination control procedures would be required for planetary protection. However, the Project would be encouraged to provide some contamination control in its own interest. There would be a requirement to document for the record the planned contamination control and to reference the expected contamination impact (microbial load) of STS operations. The latter information would be available through the PP Program based on prior investigation. Similarly, there would be no requirement for microbiological assay or microbial burden reduction for either the Orbiter or the Probe. This definite statement would resolve some of the present issues which need to be decided on a case by case basis.

The orbital lifetime and final disposition of the Orbiter issues would be moot under the proposed policy. The requirement would be to declare the Orbiter phase of the mission to be direct contact and to state the intended final target. Analogously, the Probe phase would be declared a direct contact with Jupiter.

Finally, there would be no required mathematical analysis of the probability of contamination. Accordingly, the specification by the PP Program of allocations and probabilities of growth would not be needed.

The principal PP requirements would be simplified forms of the documents called for under the present policy. The Planetary Protection Plan would describe the mission with regard to PP interests (i.e. planets involved, forms of encounter, etc.) and reference the mission planning document. The category of the mission would be declared to be Category II. The planned contamination control measures would be documented, and reference made to the expected microbial burden.

The Pre-Launch Report would document any changes from the original plan of PP significance (for approval) and review the implementation of the contamination control measures. Values of the probability of impact for those planets not intended to be impacted would also be provided. Specifically, the launch vehicle (Centaur) for the entire Jupiter system, the Probe for the satellites of Jupiter, and the Orbiter for Jupiter and all satellites, besides that one specified for final disposition in the PP Plan, would be evaluated.

The Post-Launch report would document any launch anomalies of PP significance and update the probabilities of impact cited in the Pre-Launch Report (as necessary). The End of Mission Report would document any anomalies of PP significance during the mission after launch. It would also be a record of the actual final disposition of all spacecraft hardware that impacted any planet, including location. Presumably, the Probe entered the atmosphere of Jupiter at specified latitude and longitude. and the Orbiter impacted the satellite specified in the Plan at specified coordinates and velocity.

2. Comet Encounter Missions are of significant interest to current NASA mission planning due in part to the 1985 apparition of Comet Halley. Such missions span the range from rendezvous (a close encounter with velocity matching), such as the Comet Tempel 2 phase of the once contemplated International Comet Mission (ICM), to a simple ballistic fly-by, as in the Halley Intercept Mission (HIM). There are also probes, such as the Comet Halley phase of ICM. Finally a sample return mission from Comet Halley may also be considered.

One of the first issues under the present planetary protection policy and implementation is the determination of the appropriate class for a probe or a rendezvous mission. A comet fly-by is, however, given as an example of class 2 and a sample return mission is unambiguously class 4 (Ref.A1). A casual reading of the same document would seem to indicate that a comet probe mission is class 3. However, as a practical matter, even if the comet has a physical nucleus, the probability of impact of an attempted probe with on-board navigation capability will only be 10^{-3} (Ref.A9). This value, and even smaller values for ballistic probes, would suggest that class 2 (i.e. fly-by) treatment is appropriate. Rendezvous missions might be labeled class 2 as orbiters with capability to leave the comet at end-of-mission. If a physical nucleus were found (not known at present, Ref.A9) and a "landing" were attempted, the issue of changing the class retrospectively to 3 would arise.

In any case, the present requirements include a Planetary Quarantine Plan, a Probability of Contamination Analysis Plan, a Pre-Launch Analysis of Probability of Planetary Contamination, a Post-Launch Analysis of Compliance with COSPAR Recommendations, and an end-of-project supplement. If the mission is class 3, then microbiological assays are required. The P_c analysis would need a specification of the probability of growth parameter P(g), which is not presently available. (See Ref.A9 for a recommendation of nil.) If the adopted value of P(g) is sufficiently large, a class 3 mission would require microbial burden reduction procedures and assays would be mandatory for class 2. A comet sample return mission would have to comply with the class 3 requirements for its outbound phase and certain requirements yet to be determined in order to insure that the probability of Earth contamination will be an acceptable risk" (Ref.A1).

Under the proposed policy, any cometary mission would be Category II, except a sample return mission, which would be Category V. Thus, the issue of the classification would be resolved. The general requirements for the outbound phase of a sample return mission and the entirety of all other missions would be for documentation only, as described in the main body of the report and in the previous subsection on Galileo. Specific features of a comet mission PP Plan include a description of the intent of the mission (i.e. fly-by, probe, rendezvous and landing). The uncertainty in the success of an intended impact or landing would be simply resolved by a declaration of the final actual disposition in the End of Mission Report. There would be no probability of contamination analysis, no need for a specification of P(g), no microbiological assay, and no microbial burden reduction.

The requirements for the sample acquisition and Earth return phases of a sample return mission depend on whether comets are declared "safe for Earth return". As discussed in the main body of the text, this matter would have to be established by the SSB and the various consultative committes and approved by COSPAR. If comets are safe for Earth return, there would be no requirements beyond those outlined above. If not, the requirements would include those described below for the later phases of a Mars Surface Sample Return mission.

3. The International Solar Polar Mission (ISPM) was planned as a high heliocentric latitude solar observation project consisting of a NASA and a European Space Agency (ESA) spacecraft. The spacecraft would attain the high latitude and swing back over the sun by a gravitational assist at Jupiter. Although the mission is not planetary exploration, the encounter with Jupiter requires compliance with Planetary Protection.

Under the present policy, ISPM is a class 2 mission (Ref.A1). The documentation requirements are as indicated previously for class 2 (or see Ref.A1). The required mathematical analysis for the probability of contamination must consider Jupiter and all of its satellites. The hardware with impact potential includes the two spacecraft, the launch vehicle (out of Earth orbit) and a structural adapter.

The issues to be resolved are the need for microbiological assay and for clean rooms. As in the case of the Galileo Project, these matters are intimately related to the planned STS launch. The ISPM Project intends to demonstrate that prudent upper limit estimates of the microbial burden, coupled with the small P(g) values for the Jupiter system and necessarily small probabilities of impact (a Project requirement) will obviate any need for an assay. The Project also intends to claim that the 1976 COSPAR resolution (Ref.A4) and SSB recommendation (Ref.A3) concerning the use of clean rooms do not apply to ISPM. The grounds for this position are that ISPM is not an exploratory mission to the outer planets.

Under the proposed policy ISPM would be a category II mission. There would be no requirement for any analysis, for any assay or for contamination control. The required documentation would be as noted in the main body of the report and simiiar to Galileo in detail.

4. The Venus Orbiting Imaging Radar (VOIR) mission consists of an orbiting spacecraft at Venus with rather specialized instrumentation to map the surface of the planet. Under the present policy, there is some uncertainty as to the classification of orbiters. Further, the planet itself has been declared impossible to contaminate (P(g)=0), and only the atmosphere remains a planetary protection concern.

Given that the orbit will eventually decay and the spacecraft will enter the atmosphere, VOIR is a class 3 mission under the present policy. Alternatively, the Project could plan a terminal orbit adequate to ensure a low probability of impact with the atmosphere during the period of biological exploration of Venus and obtain a class 2 approval.

In either case a probability of contamination analysis would be required and probably a microbiological assay. With a high probability of eventual impact (greater than 3×10^{-3}), a typical burden estimate (2×10^{7}), and the current specification of P(g) for the atmosphere (10^{-9}), a preliminary analysis would exceed a typical allocation (6×10^{-5}). Therefore, the assay, contamination control and even possible microbial reduction procedures would be mandated. The situation with an STS launch may be even more severe because of the higher expected microbial burden (Ref.A6). The detailed analysis would also be complicated by the difficulty of treating the contamination of an atmosphere (as opposed to a planetary surface).

The documentation requirements for this mission are the Planetary Protection Plan, Probability of Contamination Analysis Plan, Microbiological Assay Plan, Microbial Reduction Plan (possibly), Pre-Launch Analysis of Probability of Planetary Contamination, Post-Launch Analysis of Compliance with COSPAR Recommendations, and the "end-of-project" supplement.

Under the proposed policy, VOIR would be a Category II mission. There would be no requirement for analysis, assay, contamination control, or microbial burden reduction. The documentation required would be as described in the main body of the text, and in detail would be similar to that of Galileo.

5. <u>Saturn Orbiter with Twin Probes (SOP2)</u> is one proposed mission to follow up the Voyager Project. It is conceptually similar to Galileo except, of course, to the Saturn System. However, the second probe is intended for Titan, and has important planetary protection consequences. With this exception the requirements and issues for this mission are identical to those of Galileo. Accordingly, this discussion will be limited to the probe of Titan.

Under the present policy SOP2 is a class 3 mission. With the conservative estimate for the microbial burden associated with the probe of 10^8 (Ref.A6) and an STS launch and a P(g) for Titan of 10^{-10}, a typical allocation would be exceeded. Consequently, a microbiological assay and microbial burden reduction are both required, in addition to the probability of contamination analysis and contamination control. The documentation requirements are the complete set per Reference A1 (or see the preceeding discussion of VOIR).

Under the proposed policy the SOP2 mission would be Category II. The requirements would be for documentation only. The detailed documents would be similar to those of Galileo.

6. Mars Surface Sample Return (MSSR) is a generic mission where a spacecraft is landed on Mars and part or all of the landed hardware is returned to Earth with a sample of the surface. MSSR must, therefore, comply with planetary protection provisions which pertain to the protection of future science at Mars and which pertain to the protection of the Earth against back contamination.

Although the present policy embraces both of these concerns, the supplementing issuances do not really address the protection of the Earth. Specifically, the basic requirements document (Ref.A1) provides that for any sample return mission, "appropriate analyses must be performed and controls exercised, to insure that the probability of earth (sic) contamination will be an acceptable risk." However, it continues, "The requirements applicable to the earthbound portions of such missions are yet to be determined." Some studies have been performed under the PP Program which address these matters (Refs. A10 and A11). The outbound mission requirements for MSSR, a class 4 mission under the present policy, are the same as class 3 (Ref.A1).

Under the new policy, a MSSR mission would be a Category V mission. General requirements for such a mission are outlined in the main body of this report. To further detail these requirements and to assess their implications and impact on an MSSR mission, the latter will be divided into three phases:

a) outbound, (b) sample acquisition and delivery, and (c) science and quarantine investigations.

a. Outbound. Requirements for this phase provide for protecting Mars from Earth contamination. These requirements are detailed in the main body of this report under Category IV missions, and to a large extent, are similar to those imposed on and implemented by the Viking project. One notable exception is the sterilization of the complete lander/probe which, under the new implementing procedures, would be replaced by a requirement for sterilization of selected parts. This would impact favorably on the project both in terms of methods of compliance and in the design and construction of the spacecraft.

b. Sample Acquisition and Delivery. This phase of the mission begins with the acquisition of the sample on Mars and ends with the delivery of the sample to the Mars Receiving Laboratory (MRL) on Earth or Earth orbit. Included in this phase are all near Mars activities, the Mars to Earth transit, Earth entry, recovery, and transport to the MRL. Requirements for this phase will be aimed at protecting the Earth from Mars and other extraterrestrial contamination. A general outline of these requirements is presented in the main body of this report under Category V missions. Specific requirements would be developed in the near future and would be included in an official NASA implementing document similar to NHB 8020.12A (Ref.A1). It is anticipated that the major thrust of the requirements will address the sealing of the sample; verification, maintenance, and monitoring of the seal; and the means to prevent any accidental release of extraterrestrial material at the Earth. Specific requirements will also address issues and activities concerned with sample acquisition, transfer and storage, and active safety features to be used in non-nominal conditions. Furthermore, there will be guidelines for pre-project studies and research to validate PP approaches toward meeting requirements; multiple certifications will be required, at key mission milestones, to assure that requirements have been met.

c. Science and Quarantine Investigation. This phase of an MSSR mission begins with the receipt of the sealed Mars sample in the MRL. Requirements for this phase will be aimed at assuring Earth safety when the sample is released from its container and throughout the study of the sample. There will be explicit requirements for the construction, management, and containment capabilities of the MRL; an extensive PP protocol for studying the sample; guidelines for handling the sample during scientific investigations; and strict conditions and requirements concerning the ultimate release of the sample for scientific investigation outside the MRL.

In summary, the outbound phase of an MSSR mission will be favorably impacted by the new PP policy. Requirements will be somewhat relaxed from those imposed on Viking under the old policy and implementation. The other two phases of the mission will be seriously impacted by the new policy not in relative terms, since there never was a formal policy addressing those phases, but in terms of the anticipated range of requirements deemed essential for affording Earth the same protection, at the very least, as is provided for planets of interest. The extent of this impact on an MSSR project will depend on the severity of specific requirements to be developed in the near future.

B. PLANETARY PROTECTION FOR SPACE TRANSPORTATION SYSTEM LAUNCHES

The principal differences of interest to Planetary Protection for a space Transportation System (STS) launch instead of a conventional launch are the elimination of an aerodynamic payload shroud and a more contaminating environment than typically experienced by planetary spacecraft. The aerodynamic shroud is not required because the spacecraft will be enclosed in the Orbiter cargo bay during launch and ascent to orbital altitude. The additional contamination will occur because the spacecraft will be exposed to the environments of more facilities and in particular to more contaminating environments. The impact of the proposed PP policy will be to reduce the magnitude of the problem posed by the elimination of the shroud and the increased contamination.

These two matters are intimately related in terms of planetary protection. In the ground operations for a conventional launch, the contamination history of a spacecraft is independent of the launch vehicle. The spacecraft is encapsulated in the aerodynamic shroud prior to its entry into the only launch vehicle facility that it sees, the launch pad. This feature of the ground operations allows contamination control in the spacecraft assembly and checkout facilities (only) to be a useful PP requirement. Further, other PP requirements that are imposed on certain planetary spacecraft, such as microbial assay and microbial burden reduction, are made meaningful. The microbial burden values determined directly from an assay or inferred from a controlled burden reduction procedure are relevant because no further microbiological contamination of the spacecraft can occur. All that is required is a clean shroud interior. As contamination control mandated by the present PP policy provides "free" science instrument protection, the aerodynamic shroud necessitated by a conventional launch provides a "free" PP encapsulation system.

A planetary spacecraft launched by STS will be exposed to facilities <u>during and after</u> mating with its launch vehicle (e.g. an Inertial Upper Stage or a Centaur). These launch vehicle facilities include the Vertical Processing Facility (VPF), the payload canister and transporter, the Rotating Service Structure (RSS) Payload Change-out Room, and the Orbiter cargo bay for vertical payloads (typical of planetary spacecraft). Horizontally loaded spacecraft will be exposed to the Operations and Checkout (O & C) Building and the Orbiter Processing Facility (OPF) instead of the VPF and the RSS.

One approach to compliance with the requirements of the present PP policy would be to apply contamination control to these facilities as well as spacecraft (only) assembly and checkout facilities. However, these facilities have not been designed nor will they be operated as cleanrooms (class 100,000 or better). There are no requirements in the design specifications or the operational procedures for microbiological evaluation and control. The weak specifications for organic and particulate contamination in the intramural volume apply to the conditioned air at the inlet only. Where surface contamination specifications are stated, there is a "visibly clean" requirement only. Basically these facilities are poorly designed for contamination control because there were no such design requirements.

From the design and intended operations, most of the STS ground facilities will be characterized as "controlled areas" (about class 300,000[b]). Preliminary data obtained by J.R. Puleo (Ref. A13) as part of the KSC Facility Contamination Verification Test Plan (Ref.A9) shows that the OPF consistently was more contaminating than class 100,000[c] both by volumetric sampling and fallout sampling. The O & C Building had contamination levels at the upper limits of class 10,000[c]. However, activity in the building "during the monitoring period" was minimal. The reported data is of viable particulates as required for evaluation of microbial contamination. It should be noted that this effort has been terminated prior to completion. There are no plans to determine the microbiological contamination in the VPF and the RSS, the facilities through which vertically processed spacecraft must pass, or in the Orbiter bay. (All planned planetary spacecraft will be vertically processed.)

Contamination control, difficult in the ground facilities, may be impossible during launch and deployment. In addition to exposure to the bay interior and the launch vehicle, a planetary spacecraft may be sharing the Orbiter cargo bay with another payload with absolutely no microbiological controls. The launch environment will in this case redistribute the microbial load onto the planetary spacecraft. Finally the spacecraft must suffer the contaminating environment external to the Orbiter. For PP considerations, the debris cloud through which the spacecraft must pass is the main concern, since the debris will include viable particles. However the exhaust of the Orbiter's maneuvering and attitude control systems constitutes a source of organics that should be noted.

For missions where the present policy requires either a microbiological assay or a microbial burden reduction, the features of the STS ground and launch operations pose a problem. As has been noted, an assay must be performed <u>after</u> the last contaminating operation. There are two possible approaches. The microbiological assay could be performed in the RSS. The

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[b] Federal Standard 209B, Ref. A12

[c] NASA Standard NHB 5340.2, Ref. A14

Orbiter bay and the launch vehicle would have to be microbially cleaned in separate prior operations. The planetary spacecraft and its launch vehicle would have to be microbially cleaned in separate prior operations. The planetary spacecraft and its launch vehicle would have to be the only payload in the bay for the STS launch. Finally an estimated increment in microbial load due to deployment would be applied. The problems with this approach include the STS timeline (schedule doesn't allow time for bay cleaning or spacecraft assay), various jurisdictional disputes (over launch vehicle and bay cleaning), safety issues, and the additional cost of a sole launch. The data for a valid estimate of the deployment contamination is also needed. The alternative approach is to perform the assay in the spacecraft assembly and checkout facility and then encapsulate the spacecraft in a contamination shroud before it is moved to the facility (VPF or O & C) for integration with the launch vehicle. The disadvantages of this approach are the cost of the shroud, the lack of further access to the spacecraft (or alternatively the risk of a forced PP violation or launch abort), and the mission risk of a shroud deployment failure.

For missions where the present PP policy requires a microbial burden reduction, a contamination shroud is the only reasonable method. The reduction procedure and the encaspsulation would both be accomplished off (the STS) line. The spacecraft would then enter the STS operations at launch vehicle integration (VPF or O & C).

With this review of the pertinent features of an STS launch of a planetary spacecraft, the impact of the proposed PP policy and implementing issuances may now be considered. Generally the proposed policy would allow most STS launches with no special procedures to be compatible with PP requirements. For Category I missions, which have no PP requirements, there is no effect of the STS launch facilities and procedures at all, for example.

Under the proposed policy only minor PP requirements at most would be imposed, as a result of the STS system, on Category II missions. Basically, the largely unknown but putatively high microbial contamination due to STS operations does pose a problem for the acceptance of the policy. The resolution of this problem requires prior measurements of the microbial contamination levels of the facilities by the PP program one time only. With this data, the estimated typical spacecraft microbial burden could be accepted by PP for Category II missions. That is, standard STS procedure and specifications would be approved for Category II missions. Alternatively certain minor improvements in procedure could be specified in the implementing issuances (e.g., replacement of the bay liner, tenting of the spacecraft, etc.). However, exhaustive and expensive procedural requirements would violate the intent of the proposed policy. For this reason a requirement for a contamination shroud is not recommended for Category II missions. For Category III missions, the requirement for passive bioload control in the face of an STS launch will be definitely reflected in the PP implementing issuances. In this case, not only must the expected contamination due to standard STS operations have been previously determined (as needed for Category II), but also the efficacy of special contamination control procedures. These contamination control procedures would be documented as requirements in the implementing issuances for STS launched Category III missions. Depending on the determination of the contamination, these special arrangements (special to standard STS operations) might include bay liner replacement, spacecraft tenting, enhanced personnel garmenting and access control, facility cleaning (such as the bay itself), and facility microbial assay. The mission should also be given the alternative, as an option, of employing a contamination shroud.

For Category IV and Category V (priority C target planet) missions, the obvious recommendation is the requirement of a contamination shroud. This is a severe and costly requirement, but the only logical choice. Some cost sharing may be possible, however, in that the contamination shroud will also function as a bioshield in the conventional sense.

C. SCIENCE INSTRUMENTS AND PLANETARY PROTECTION POLICY

There are two ways that biological and chemical contaminants can affect scientific results in the planetary exploration program. One mode is the contamination of the environment of a planet (or other body) so that the opportunity to make future observations of the original state of the planet is lost. The second route is the contamination of payloads and scientific instruments causing scientific determinations to be erroneous.

The purpose of the NASA Planetary Protection Program is to preserve the original state of the planets by preventing their contamination. To accomplish this, requirements and constraints have been developed that are applicable to various missions. The program does not specifically protect scientific payloads or instruments. In fact, scientific payloads are subject to the same requirements and constraints as any spacecraft hardware in terms of allowable microbial burden and organic chemical contamination.

However, there have been instances where the implementation of bioburden reduction and cleaning procedures for the spacecraft incidentally provided contamination protection for scientific payloads. Also, in the past, the Planetary Protection Program has provided contamination control, cleaning and sterilization for certain biological instruments on an exceptional basis, specifically for the Viking mission. In these cases there were system requirements for the instruments more stringent than those imposed on either the spacecraft or the instruments by planetary protection. Although this was not a Planetary Protection Program responsibility, it was convenient to utilize the unique capabilities developed for the program.

Under the proposed policy, the Planetary Protection Program will have no responsibility for, and will not provide, contamination control or bioburden reduction services for science payloads. This responsibility will be assigned to the appropriate principal investigators and the project offices. Note that the need for contamination control for science instrument protection may be enhanced, with the relaxation of Planetary Protection requirements for spacecraft. For missions involving the return of extraterrestrial samples to Earth, this same assignment of responsibilities will be made for the preservation of the integrity of the sample during the total mission. In addition, the Planetary Protection Program will not be responsible for any damage to scientific instruments or for any morphological, chemical or biological changes in a returned sample caused by the project's implementation of planetary protection requirements.

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