AN OVERVIEW OF PLANETARY QUARANTINE CONSIDERATIONS FOR OUTER PLANET PROBES

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MR. HOFFMAN: You have given a brief introduction to the problem of planetary quarantine and I will discuss today an overview of this subject as it pertains to the outer planets. To that end, I will be covering the topics that are listed below:

TOPICS

- o BACKGROUND
- o PLANETARY QUARANTINE CONSIDERATIONS
  - o PRELAUNCH
  - o LAUNCH AND SPACECRAFT
  - O BASIC CONTAMINATION EQUATION
- o CONCLUSIONS

I will start with an introduction and give some background relative to where we receive our planetary quarantine requirements, the international and national policy and how a flight project gets those requirements and what a flight project does with them. Then I will trace the planetary quarantine considerations through the life of a flight project assuming that a planetary quarantine requirement has been imposed. We will mention the considerations that pertain to the pre-launch phase, the launch-and-space-flight phase and then comment on the basic differences between a Mars lander and an outer-planet probe, and relate that to the basic contamination equation. And, finally, draw some conclusions relative to the significance of planetary quarantine for outer planet probe missions.

Turning to the background, Figure 9-1, as many of you are aware, the international policy for planetary quarantine is established in the Outer Space Treaty that was signed in January of 1967. In that, there is a phrase that states that the participating nations flying missions to the planets will take measures to prevent their harmful contamination.

PLANETARY QUARANTINE BACKGROUND

- INTERNATIONAL POLICY
  - OUTER SPACE TREATY
  - COSPAR

- NATIONAL POLICY
  - NASA
  - SPACE SCIENCE BOARD

- PROGRAM PC ICIES
  - NASA PQ OFFICER
    - PQ PROVISIONS (NHB 8020.12)
    - P_C AND P_G FOR PLANETS
  - PQ PLANNING
  - ANALYSIS AND DOCUMENTATION

FIGURE 9-1

The International Council of Scientific Unions has established a Committee on Space Research, COSPAR, that establishes the guidelines and passes resolutions that relate to the international policy. The policy, as far as the United States is concerned, is established by NASA. NASA establishes that policy based on recommendations of Space Science Board. One of the purposes of having the seminar that Mr. Toms was referring to relative to the outer planets is to determine those planets of biological interest so that the Space Science Board can provide recommendations to NASA to establish the national policy relative to outer planets.

As far as program policy and how it is transmitted to a flight project, the NASA Planetary Quarantine Officer, at Code SL, provides to the Program Manager the PQ provisions document (NHB 8020.12), and two parameters for each planet or satellite of biological interest; one, a probability of contamination number (PC) and a probability of growth number (PG).

Then the flight project, based on the information that has been provided, begins its planning function and generates a planetary quarantine plan and, as appropriate, any subsidiary plans, such as a microbiological monitoring plan and a sterilization plan and, if necessary, a decontamination plan.

Then a flight project proceeds into the implementation phase of the planetary quarantine effort. The project performs some analysis; documents the results of that analysis and the microbiological monitoring; and generates such documents as a pre-launch analysis document and following the launch of the spacecraft, the post-launch analysis document.

On Figures 9-2 and 9-3 I will walk you through the life of a typical flight project, starting with the pre-project planning. (Outer-planet probes are currently in the pre-project planning phase.) In the pre-project phase we evaluate the effects planetary quarantine will have on the mission strategy, trying to formulate any impact that PW would have on these mission constraints. We try to determine what planetary quarantine analytical tools are

PLANETARY QUARANTINE CONSIDERATIONS

Prelaunch Phase

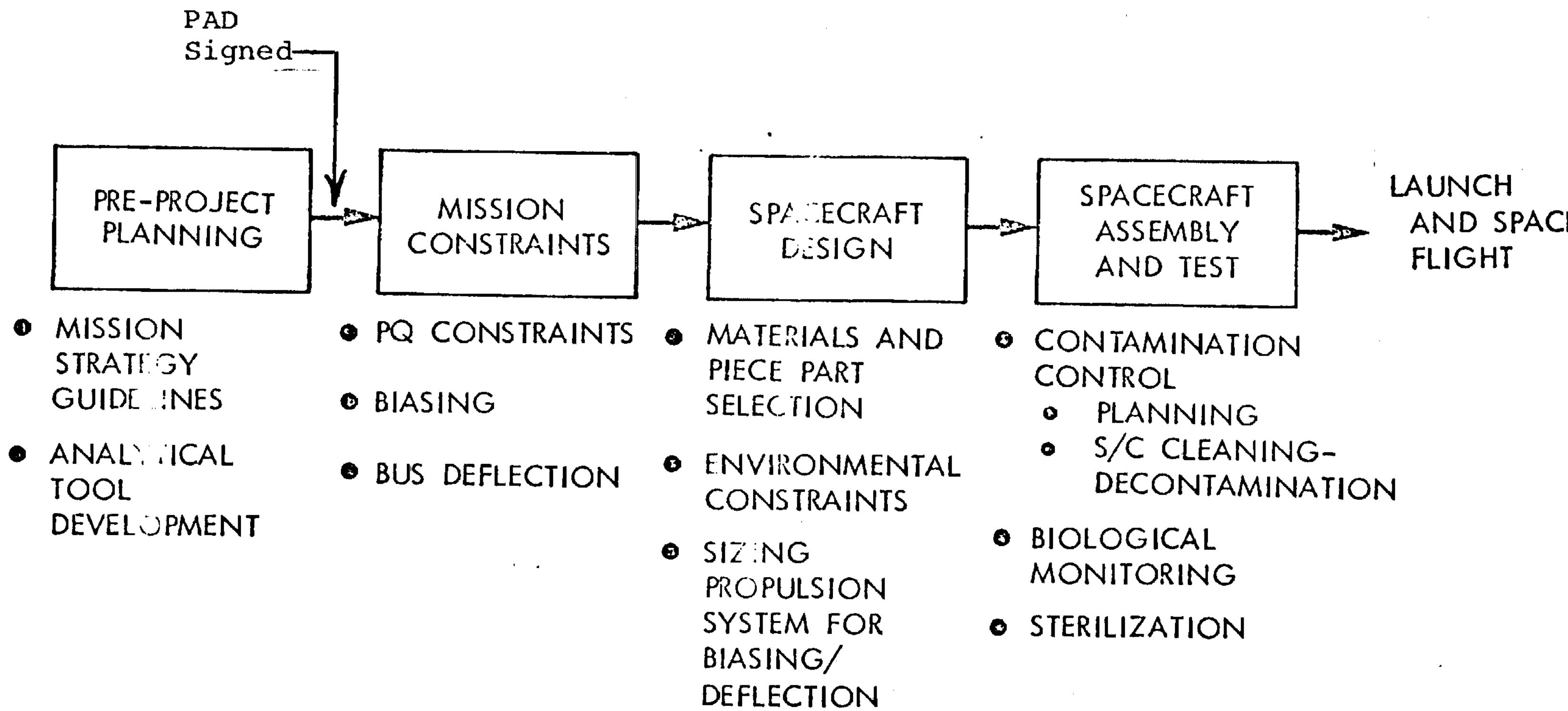

Figure 9-2

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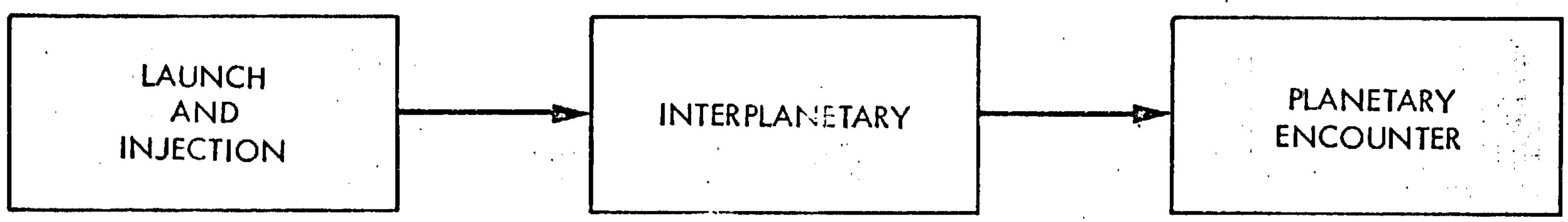
PLANETARY QUARANTINE CONSIDERATIONS

Launch and Spaceflight Phase



LAUNCH AND INJECTION

- BIASING
- RECONTAMINATION OF STERILE HARDWARE

INTERPLANETARY

- BIASING
- EXPOSURE TO NATURAL SPACE ENVIRONMENTS
  - VACUUM
  - SOLAR IRRADIATION
  - SOLAR WIND
- RECONTAMINATION OF STERILE HARDWARE

PLANETARY ENCOUNTER

- BIASING
- BUS DEFLECTION
- ORBITAL LIFETIME
- EXPOSURE TO NATURAL SPACE ENVIRONMENTS
- RECONTAMINATION OF STERILE HARDWARE
- ENTRY HEATING

Figure 9-3

lacking and need to be developed for such things as bus deflection, biasing, and other navigation and trajectory considerations.

The project approval document (PAD) is signed at the point indicated. The project then proceeds into developing mission constraints and spacecraft design. Listed are some of the PQ considerations that are considered during these phases. For example, for biasing and bus deflection, planetary quarantine has an effect on how one sizes the propulsion system; i.e., the weight penalties that are attributable to planetary quarantine for performing these types of maneuvers.

If the project is going to have a sterilization or, a microbical reduction of some sort, then materials and piece part selection becomes a very important part of your spacecraft design.

Also considered during this portion are the environmental constraints that have a bearing relative to planetary quarantine. For example, as will be noted later, the natural space environments and, in particular the encounter environments, can have a reduction effect on the number of micro-organisms on the spacecraft arriving at the planet. These environments should be considered in the spacecraft design and can influence the stringency of the sterilization cycle.

Going into the spacecraft assembly and test operations, the contamination control planning effort, one looks at the considerations relative to the facilities that are needed to assemble the spacecraft and also, the personnel constraints and any special cleaning and decontamination methods.

If biological monitoring is required, it would te performed during this phase and then, as I have mentioned earlier,a terminal sterilization (i.e. microbial reduction process) of some sort may be required.

The next phase is the launch and spaceflight. On Figure 9-3 I have divided this into three areas: launch and injection, interplanetary, and planetary encounter. The biasing for planetary quarantine reasons has been a mode that we have been using on the majority of our missions that have been flown in the past where we biased the aim point away from the planet and then, by subsequent trajectory correction maneuvers, correct back to the desired aim point. This has a certain delta-V and weight penalty associated with it.

Also, if we are dealing with sterile hardware, (i.e. a probe sterilization has been performed), then the recontamination from a non-sterile bus is an important consideration in all three of these phases.

During the interplanetary phase, we have reduction techniques from the natural space environment that may reduce the viability of the micro-organisms that are on spacecraft exposed surfaces; such things as vacuum, solar irradiation, and solar wind.

Then finally, at the planetary-encounter stage, the things that need to be considered are the bus deflection, and if we are flying an orbiter, orbital lifetime. Then the exposure to natural space environments such as the trapped-radiation belt at Jupiter, may reduce the number of viable micro-organisms as well as entry heating. Recontamination I have already discussed.

What is uniquely different relative to Mars landers and outer planet probes is the planetary-encounter phase; in particular, the degree of entry heating that one would encounter. This can best be illustrated by Figure 9-4. This figure gives the basic contamination equation given entry and it applies for either inadvertent entry or the entry of a probe. It gives the number of viable organisms on the body at the time of entry times the probability of surviving atmospheric entry, the probability of release, and the probability of growth. This is important, during the planetary-encounter phase because if the probability of surviving atmospheric entry is very small that means that the number of viable organisms can be large at the time of encounter which in turn, maps back to what the launch burden can be, which in turn maps back to the stringency of the sterilization requirement.

BASIC CONTAMINATION EQUATION GIVEN ENTRY

$$P_{C|E} = n \; P_{SA} \; P_R \; P_G$$

WHERE

$P_{C\|E}$	IS	PROBABILITY OF CONTAMINATION GIVEN ENTRY
n	IS	NUMBER OF VIABLE ORGANISMS ON BODY AT TIME OF ENTRY
P_{SA}	IS	PROBABILITY THAT A GIVEN ORGANISM SURVIVES ATMOSPHERIC ENTRY HEATING
P_R	IS	PROBABILITY THAT A GIVEN ORGANISM IS RELEASED IN A REGION OF BIOLOGICAL INTEREST IN THE ATMOSPHERE
P_G	IS	PROBABILITY OF GROWTH

Figure 9-4

So, if P_{SA} is sufficiently small, the stringency of the sterilization requirement may be considerably less than what it is for Mars if there is any sterilization requirements imposed on outer planets probes.

Finally, Figure 9-5 has the three messages that I would like to leave with you today, as an overview: for the time being the planetary quarantine provisions of NHB 8020.12 are applicable to probes; as far as the interaction between the encounter environments and the stringency of the pre-launch sterilization requirements, this should be taken into account during early probe studies; and the information that we have learned during the course of doing the planetary quarantine work forthe Pioneer, Mariner, and the Viking programs, forms a basis for doing planetary quarantine work for the outer-planet probes.

This has been an overview of the planetary quarantine as it currently exists. There are unknowns relative to which planets are of biological interest to us. I understand that at some point in the near future that a position paper will be released by or through the NASA Planetary Quarantine Program Office on the outer planets. And that would be made available to the aerospace community.

MR. TOMS: Our next speaker is Bob DeFrees from McDonnell-Douglas who is going to talk about the impact of planetary quarantine on probe design.

CONCLUSIONS

- PQ PROVISIONS OF NHB 8020.12 APPLICABLE TO PROBES

- INTERACTION BETWEEN ENCOUNTER ENVIRONMENTS AND STRINGENCY OF PRELAUNCH STERILIZATION REQUIREMENTS

- PIONEER, MARINER, AND VIKING PQ EXPERIENCE AND ANALYSES FORM BASIS FOR QUARANTINE WORK

Figure 9-5