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TECHNICAL DISSERTATION

SW-1980

MICROSCOPIC SYSTEM FOR MARS

STUDY PROGRAM

Jet Propulsion Laboratory  
California Institute of Technology  
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## I. SCOPE

This document describes the requirements of a study program for the Microscopic System for Mars. It is the intent of this study program to obtain basic information to establish the design parameters for the development of an extra-terrestrial life detection system. This system will be used to explore the microbiological environment of the planet Mars.

## II. REQUIREMENTS

### A. The Study Program

1. The Contractor shall conduct a five-month study program and shall recommend what optical, mechanical, and electronic principles, methods, or techniques will show the most promise in devising the complete system. The Contractor should also evaluate any special research and development programs that would advantageously advance the state-of-the-art for the purpose of this program. The Contractor should orient his study to the operational spacecraft and planetary surface environment. The final result of the study should be a detailed analysis of the methods, techniques and principles required for the successful operation of the microscope mission and an outline for a breadboard model. This outline should not include detailed drawings; the analysis should include preliminary considerations on the trade-offs between weight, power, and volume requirements versus reliability, and the data that can be acquired.
2. The Contractor shall submit a first written report one month from the date of the awarding of the study contract, and shall follow this first report with four successive monthly progress reports, each due one month from the date of the previous report. Two weeks following the completion of the five-month study period, the Contractor shall submit to the Jet Propulsion Laboratory a final summary report which shall include all phases covered in the study, a recommendation covering the kinds of optical, mechanical, electronic, or other approaches he feels should be used in devising the microscope system, and a proposal of a preliminary design of the instrumentation on the basis of his study. All monthly progress reports should be as short and concise as possible using sketches where needed in lieu of detail drawings and should only discuss new material not previously reported. It will also be required that he provide cost and time estimates for actual development of the instrument system.

The five monthly reports prepared by the Contractor should be submitted in quadruplicate, including one reproducible copy of text and sketches.

Ten copies of the final report will be required, including one reproducible copy of text and drawings.

## B. System Description

### 1. Functional Description

The system will operate from a spacecraft soft-landed upon the surface of the planet and will require either pre-programmed automation or a system of built-in logic to control the necessary manipulations and to process data obtained for the spacecraft telemetry system.

The system will be designed to collect and concentrate particulate samples from the surface and atmosphere of the planet. These samples will be observed by microscopy to furnish images of particles that may resemble microorganisms in respect to phase contrast and form.

For convenience, the microscope may be divided into three subsystems:

- (1) The sample collection, preparation, manipulation, and delivery system which includes all instrumentation up to, but not including, the stage of the microscope.
- (2) The optical system. This includes the optics, the stage, the substage, and the illumination system.
- (3) The electronic system. Subsystem 3 is, however, not part of this work statement and will be handled separately.

### 2. General Specifications

#### a. Sample Collection and Preparation

The microscope system must provide the following capability:

- (1) Collect samples in the form of particulate material from a variety of surfaces comparable to frozen clay, dusty soil, sand, gravel, scrapings from hard rock, and atmospheric aerosols.
- (2) Fractionation of Sample:
  - (a) Remove particles whose size would interfere with the operation of the microscope.

- (b) Fractionate the sample according to mass densities greater than 1.2 and less than 1.2.
  - (c) Sort the sample into size groups which are optimum for viewing under low, medium and high magnifications.
- (3) Concentrate the refined samples on an object support which will provide optimum conditions for microscopic observation. The system should permit separate observations on both high and low density fractions as described in paragraph (2) (b) above.
  - (4) The system should be capable of transporting the object carrier to the stage of the microscope.

b. Microscope System

- (1) The microscope will provide auto-focusing. In response to signals from the electronic logic system, it should be capable of horizontal alignment of the object carrier so as to center a particle on the optical axis to a precision of  $0.2 \mu$ .
- (2) At high magnification, it should provide an object field of 20 microns diameter at a resolution of approximately 0.2 microns and project a focussed image of 1.8 cm diameter on the image plane, e.g. vidicon target plate. It should provide an object field of  $100 \mu$  diameter, at medium magnification and  $500 \mu$  diameter at low magnification. The image should have an intensity of 0.5 to 10 foot candles.
- (3) The microscope should be capable of transmission and color phase contrast. Corresponding filters should be furnished to allow observation alternatively in phase contrast and transmission modes.
- (4) As an option, the microscope should be capable of incident illumination through the objective lens and consideration should be given to the optimum optical qualities of the object carrier, e.g. whether this should be opaque, reflective, or transparent for optimizing the detail that can be observed in the sample. With a view to compact design of an incident illumination system and economy of power, the feasibility of incorporating a miniature light source within the objective should be considered.

c. Other Requirements

- (1) The system must be capable of collecting and processing up to 100 grams of crude sample for each observation cycle, and should be capable of repeating at least twenty-five cycles for the complete mission.
- (2) The system must remain in stand-by condition during the time of transit of approximately 220 days, and be capable of operation for about thirty days after landing.

### III SPACECRAFT AND PLANETARY ENVIRONMENT

It is not possible at this time to provide detailed descriptions of the spacecraft environmental restrictions nor complete descriptions of the Martian environment. However, it is possible to suggest working specifications which can be used as a guide for the present study. To some degree, the design of the spacecraft will be influenced by the requirements of the scientific experiments it is required to carry. Therefore, the following approximate values are suggested:

A. Spacecraft Environment Requirements

1. Volume of Microscope System: less than 1200 in.<sup>3</sup>.  
With sample handling using approximately 800 in.<sup>3</sup>  
and the optical system 400 in.<sup>3</sup>.
2. Allowable Weight of System (Including Electronic System):  
less than 12 pounds.  
Sample handling weight approximately 5 pounds and  
Optical System weight approximately 3 pounds.  
Electronic System (JPL-supplied) weight 4 pounds.
3. Permissible power consumption 20 watts for 5 minutes  
less than 2 watts continuous per operating cycle.
4. Bandwidth available: less than 200 cps.
5. Maximum expected g-load: 100 g for 20 ms.
6. 20 g rms noise band limited 20-5KC for 10 minutes.

B. Planetary Environment

Some of the salient features of the Martian environment are:

1. Atmospheric Pressure: 60-70 mm Hg.

2. Temperature Range: Plus 30°C to minus 80°C.
3. Average Solar Constant: 0.86 Cal/cm<sup>2</sup>/min.
4. Water Vapor Pressure:  $\approx$  0.002 x earth.
5. Gravitation: 0.37 x earth.

#### IV BACKGROUND INFORMATION

Terrestrial soil is considered as a prototype of the sample that will have to be analyzed. Such soils have an organism content varying from some hundreds to some millions of microbes per gram and the design efforts will have to be focused to the lower extreme of this range, say: 10-1,000 organisms per gram. These microorganisms include a wide variety of biological forms; the most numerous, however, are bacteria, whose characteristic dimensions are from 1-10 microns in simple spherical, cylindrical, and sometimes helical forms. It is the aim of the present system (1) to achieve as far as possible a preliminary concentration of microorganisms from a sparsely inhabited soil and (2) to detect these microorganisms by their properties of form and transparency under the microscope. For the first objective, flotation in a medium of appropriate density, about 1.2, has been quite promising in preliminary experiments and, with careful mixing of the soil, a large proportion of the microorganisms can be extracted by flotation. The material "Ludox," a colloidal dispersion of silica furnished by Dupont, has been successfully used in these experiments and has the particular advantage of preserving the viability of most microorganisms. However, this fluid is not necessarily the most suitable for the present purposes which, in any case, do not now require that the organisms be viable at the time of examination. Other heavy fluids should, therefore, be examined for their suitability for this purpose. One disadvantage of Ludox is the possibility of its instability over long periods of time, particularly under temperature stress. In selecting a flotation fluid, attention should be given to the preservation of the form of the microorganisms and the ease of dissociation of the organisms from the particles of soil to which they may be adherent. For the efficient separation of the microbes, it may be necessary to arrange for the preliminary agitation of the suspension of the soil in the flotation fluid.

In order to extract as many bacteria as possible with a given volume of flotation fluid, it would be desirable to have a compact continuous flow sedimentation which could process several volumes of soil with one volume of fluid. If this is not feasible, the geometry of the sedimenter should be such as to concentrate the light fraction containing the organisms in the smallest usable volume, as it will be difficult to scan very large volumes at high magnifications with the microscope.

For the microscopic observation, phase contrast is presently indicated as the most convenient means of recognizing microbes, especially since these are usually transparent when suspended in aqueous solutions and examined with visible wave lengths. The use of color phase contrast should facilitate the discrimination of transparent but phase-retarding particles like microorganisms from other components of soils. Then with the alternation of the appropriate filters, comparison images will indicate which particles have these properties.

Incident illumination is indicated as an approach to a possibly more compact design for microscopy on a marginal mission, for example, the study of the particles that may be merely collected on the window of an objective lens cap. Incident illumination may also be particularly advantageous for the examination of lunar as well as planetary soils from a geophysical as well as a biophysical standpoint.

The system as a whole may be considered successful in relation to its success in the detection of evidence of microbial life in the sparsest of terrestrial soils, for example, desert sands which may have a density not greater than 100 organisms per gram. Since the conditions for life at the point of landing on Mars may be even more marginal than at any point on the earth, it would be desirable to have a further leeway in sensitivity of an additional two or three orders of magnitude.

The system should also include an internal means of calibrating its functions; for example, well defined and easily recognized test objectives having considerable detail should be included at least in the microscopic observation and perhaps even in the sample inputs.

## STATEMENT OF WORK - MICROSCOPIC SYSTEM FOR MARS (SW-1980)

I. Introduction

The Jet Propulsion Laboratory is initiating a five month program of study to obtain basic information needed to establish the design parameters for the development of an extra-terrestrial life-detection system which will be used to explore the micro-biological environment of the planet Mars. The system will operate from a spacecraft soft-landed upon the surface of the planet and will require either pre-programmed automation or a system of built-in logic to control the necessary manipulations and to process data obtained for the spacecraft telemetry system.

The system will be designed to collect and concentrate particulate samples from the surface and atmosphere of the planet. These samples will be observed by microscopy to furnish images of particles that may resemble microorganisms in respect to phase contrast and form.

For convenience, the microscope may be divided into three subsystems:

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II. Scope of Study

The contractor shall recommend what optical, mechanical, and electronic principles, methods, or techniques will show the most promise in devising the complete system. The contractor should also evaluate any special research and development programs that would advantageously advance the state-of-the-art for the purpose of this problem. The contractor should orient his study to the operational spacecraft and planetary surface environment.

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### III. Technical Requirements

#### A. General Specifications

##### 1. Sample Collection and Preparation

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- c) Concentrate the refined samples on an object support which will provide optimum conditions for microscopic observation. The system should permit separate observations on both high and low density fractions as described in IIIAc.
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- d) As an option the microscope should be capable of incident illumination through the objective lens and consideration should be given to the optimum optical qualities of the object carrier, e.g. whether this should be opaque, reflective, or transparent for optimizing the detail that can be observed in the sample. With a view to compact design of an incident illumination system and economy of power, the feasibility of incorporating a miniature light source within the objective should be considered.

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- 3) Average Solar Constant: 0.86 Cal/cm<sup>2</sup>/min.
- 4) Water vapor pressure:  $\approx$  0.002 x earth.
- 5) Gravitation: 0.37 x earth.

V. Reports

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V. Proposal

Prospective study contractors who wish to participate in this program are invited to submit proposals to the Jet Propulsion Laboratory. The prospective contractor may submit a proposal covering either or both of the subsystems described in paragraph I, depending upon his interest and discretion. It is expected that the proposals shall provide the following information:

- A. What will be the major objectives of this study?
- B. How will the contractor organize the study program to achieve these objectives?
- C. What does the contractor consider will be the most important technical

problem areas?

- D. How will the contractor seek solutions to these problem areas?
- E. What experience has the contractor had to qualify for this study?
- F. Specifically, whom of the contractors technical personnel will be assigned to this study. How much time will each person devote to fulfilling his duties in this contract?
- G. The contractor should indicate whether or not he desires to perform a study of both subsystems or restrict himself to one of the subsystems listed in I.
- H. What is the contractors cost estimate for this study?

Once the contract has been awarded, JPL will provide all pertinent information it may possess and will work closely with the study contractor during the duration of the contract.

Although it is intended to follow the preliminary study with further design and development contracts, it is emphasized that this preliminary study is a separate effort and no commitment to a follow-on development contract is or has been made.

#### VI. Background Information

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