ADM: ORG: NAS: Space Sc B
Meetings: Problems of Detecting Extraterrestrial Life: Cambridge (Mass)

19-20 Dec 1958

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SPACE SCIENCE BOARD

Meeting on the Problems of Detecting Extraterrestrial Life

Massachusetts Institute of Technology

December 19 and 20, 1958

Participants:

Cowie	Hartline	Miller	Vishniac
Davies	Kamen	Rossi	Billings
Derbyshire	Levinthal	Schmitt	Freeman
Doty	Luria	Sistrom	Young
Gold	MacNichol	Townsend	

Introduction

Section A describes what is known about the physical conditions of Mars and Venus and, briefly, some of the chemical and biological processes which may occur on these planets. Section B gives a projected time table for planetary probes, satellites or landings on Mars or Venus. Section C contains suggestions and recommendations for use of these launchings for scientific purposes.

A. The Environments of Mars and Venus and Relevant Terrestrial Concepts

It should be noted that observations of spectral absorption features produced by constituents of the atmospheres of Mars and Venus are difficult or impossible when these features are strongly masked by the same constituents in the earth's atmosphere. The figures quoted for percentage of oxygen, water vapor and so forth are all upper limits which, of course, vary from constituent to constituent according to the masking ability (essentially, line widths) and from planet to planet according to the maximum differential radial velocity available to cause doppler-shift of the planet's lines in relation to those of the earth's atmosphere. When a spectroscope with sufficient stability and resolving power can be flown above the earth's atmosphere, it will be possible to fill many of these observational gaps.

1) Mars (cf. Science 128, 89, 1958)

a) Atmosphere CO_2 content is high, about 20m at terrestrial standard temperature and pressure (this may be in error by a factor of 5). Nitrogen is probably present, but the amount is unknown. Oxygen has not been detected but, if present, is less than 1% earth oxygen content.

Oxygen and water: Not observed; upper limit is less than 5% of the terrestrial content.

Nitrogen: No evidence available. There is some evidence for an N_2^+ emission spectrum from the night side.

Clouds: The Venerian cloud cover is nearly opaque; as a result, its mass and composition are relatively unknown. A certain amount of structure in the atmosphere of Venus is, however, detectable in UV photographs: regions of slightly greater than average albedo with dimensions of the order of 1000 km.

b) Temperature The temperature has been observed with radiometric devices to be 50°C at the subsolar point outside the opaque part of the atmosphere and -40°C on the dark side. At radio wavelengths the temperature has been observed to be in excess of 200°C. The specific layer from which infrared radiation originates is somewhat open to question, but the radio waves are presumed to refer to the surface of the planet.

c) Gravity Mass .82 times earth, density .89 times earth, surface gravity .86 times earth.

d) Irradiation Because of the unknown nature of the clouds and magnetic field the surface irradiation spectrum is unknown.

3) Evidence for Organic Matter on Mars

Sinton's work: (cf. Astrophys. J. 126, 231, 1957)

All C-H bonds (in compounds heavier than methane) give rise to infrared absorption bands near 3-4 μ. In large organic molecules the resonance occurs near 3-46 μ (the precise wavelength depending on the neighboring atoms) and when two hydrogen atoms are attached to the same carbon atom, the band is a doublet with the mean wavelength again near 3-46 μ. Sinton detected this band on Mars (published data) and showed its association with the dark patches (unpublished data). Most terrestrial plants display a near-infrared reflectivity which is not seen on Mars. Sinton mentions that some lichens show reflection spectra similar to that of the planet and he suggests that if vegetation exists on Mars it may resemble these lichens. A more likely possibility is photosynthetic bacteria, as the following consideration shows.

The high reflectivity in the near-infrared of green plants referred to by Sinton begins at about 750 mμ and extends to about 1500 mμ; it is caused by the absence within plants of compounds absorbing at these wavelengths. Some lichens apparently have absorbing compounds. It can be predicted that photosynthetic bacteria will also have a low reflectivity in this region since bateriochlorophyll (found in purple photosynthetic bacteria) absorbs in the region from 800-900 mμ. The chlorophyll of green plants absorbs in the region 600-700 mμ, that of the green photosynthetic bacteria (Chlorobium) 700-800 mμ. On

Luria pointed out that this sort of picture, and also less explicit ideas about the nature of Martian life, are based on the assumption of a "closed ecology", that is, one in which the total amount of biological matter remains constant. The earth and Vishniac's mixture of photosynthetic and sulfate-reducing bacteria are examples. It is conceivable, however, that the planets may have an "open ecology", in which the amount of biological material is increasing, or in which there is no cycling of matter between different kinds of living things but a one-way channeling of available organic material into living things. The earth at a time between the first origins of life and the present steady state ecology would serve as an example.

B. Projected Time Table for Planetary Probes, Satellites or Landings on Mars or Venus

1) Davies presented a very rough timetable of planetary satellites:

1960 - 200 lbs. payload in general vicinity of Mars and Venus (perhaps as close as 10^6 miles).

1961 - Soft lunar landing

1962 - An entry or moderately hard-landing on Mars or Venus

1964 - Venus soft-landing, or orbit and return

1965 - Mars soft-landing, or orbit and return

The soft landings in 1964-65 could land about 500 lbs. of instruments. The possibility of landing and return is remote.

2) Balloons and earth satellites

3) Terrestrial experiments and observations

4) Infrared (an ultraviolet) narrow band-pass filters for use on both earth and planetary satellites were discussed.

C. Suggestions and Recommendations for Further Observations and Experiments

For convenience, we list suggested observations and experiments under each of the possible locations or conditions: (1) In the earth; (2) from balloons or earth satellites; (3) from satellites in orbit around the planets; (4) hard-landings; (5) soft-landings.

1) Experiments on earth

a) Extension of Miller's experiments to conditions such as may obtainoon Mars or Venus (different temperatures; various water contents, UV irradiation levels, and atmospheres). These experiments can be designed more effectively when more is known about the atmospheres of the planets. Most of the work done now in this field is concerned with the development of life on earth;

3) Observations from near-miss or hard-landing

a) Photographs at various wavelengths to estimate the spatial distribution of any absorption bands found by spectroscopic examination from earth satellite. Narrow-band-pass infrared filters might be very useful.

b) Physical measurements: cosmic ray, magnetic field, temperature, mass spectroscopy of the atmosphere.

c) On a Venerian hard-landing: chemical composition of the cloud.

d) Detection of surface roughness by radar may be easier from a near-miss (extra-atmospheric orbit) satellite than from earth.

e) A hard-landing contamination risk: (see under Section C, 4, a, iv).

4) Observations from a soft-landing

a) Contamination The physical and chemical observations discussed above would be made even apart from any biological interest in the planets. Observations made after a soft-landing will answer more specifically biological questions. It is difficult to suggest observations, because the properties of the possible biological processes are uncertain: a cosmic ray is a cosmic ray, but a Martian organism (if any) may be very different from any terrestrial organism. Before mentioning the kinds of observations that were suggested, we outline the discussion on the problem of contamination, which must be considered in any soft-landing attempt.

i) A variety of possible biological states of the planets can be considered: a. living things essentially identical to those found on earth; b. living things similar in gross metabolic aspects to terrestrial forms with important differences in structure and metabolism; c. living forms basically different from terrestrial forms, for example, anhydrous or silicon-based forms; d. some form of "proto-life", either extensive or marginal; e. the planets are totally sterile; f. the planets, now sterile, may harbor remains of an earlier life.

ii) The demonstration of any one of these states is of extreme importance to biology.

iii) Each state will be very sensitive to contamination from the earth, for example, possibility (d) probably implies the presence on the planet of a rich organic medium (Oparin's "soup"). This may support growth of terrestrial organisms which are marginal by terrestrial standards, but could readily outstrip the "proto-life".

Suggestions of compounds to be looked for included: amino acids, purine pyrimidines, phosphates, sulfides, fatty acids and amines. It was recommended that the aid of several analytical chemists be enlisted. The equipment for this analysis could be enclosed in a 'box' and would include devices for sampling the environment.

b. Biochemical analysis. A biochemical analysis can be carried out by inoculating terrestrial organisms of known metabolic patterns into samples of the environment, either alone or mixed with known constituents. For example, if sulfate is added to a sample of the planet surface and the mixture provided with an anaerobic atmosphere and inoculated with a bacterium which can grow by the reduction of sulfate with organic compounds as hydrogen donors, growth of this organism would indicate the presence of organic matter of a particular type. This method may not give any more information than the direct chemical analysis, and involves considerable danger of contamination.

iii) Biological Analysis This could be approached in two ways: first, to see if there occur on the planets any chemical changes that might be ascribed to metabolic reactions; second, to see if organisms exist which are capable of metabolizing in media of known composition: these two approaches may be characterized as analysis by non-intervention and analysis by intervention.

a. Non-intervention. For this a small portion (perhaps of the order of a cubic meter) of the surface would be isolated from the planetary environment and changes in chemical composition looked for. A means of periodically excluding light can also be provided. Compounds which might show changes include: CO_2, O_2, N_2, NH_3, CH_4, H_2S, H_2O, amino acids, fatty acids, etc. An important factor is the time period of observation; this should be longer than the time required on earth, since the metabolic processes may be marginal and very slow.*

b. Intervention. Essentially this is the use of the "enrichment culture" technique. This means providing a variety of known environments and substrates and observing if growth occurs upon the inoculation with samples of the planets surface. Test if simple protection from ultraviolet light (on Mars) and maintenance of different

* A metabolic process is not necessarily a rapid one. Most terrestrial ones are rapid because of the selective pressure under which they have evolved. A micro-organism trying to compete with terrestrial bacteria and having a generation time 100 times longer would not last for very long; but it might be a dominant organism in a place where no great pressure for rapid growth exists. This points up the severity of the danger of contamination of an open ecology.