Panel on Radiation Biology

Environmental Biology Committee, Space Science Board, National Academy of Sciences, National Research Council

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S P A C E S C I E N C E B O A R D

Environmental Biology Committee

Panel on Radiation Biology

The Space Science Board has undertaken to study several aspects of the space program which involve biological interests. These topics are of two kinds: those which concern the sustaining of man in space flight and those which concern the potential contributions to biology itself which may come from the ability to conduct experimental investigations in space.

This report is on a subject of the latter kind and discusses, from a fundamental point of view, radiation biology in space research. It was prepared for the Space Science Board in August 1962 by a panel of the Committee on Environmental Biology and is now released for general distribution. The treatment given here complements and amplifies the findings of the Space Science Summer Study (Chapter 9, "A Review of Space Research" NAS-NRC Publication 1079) and the First Summary Report, Working Group on Radiation Problems, Man in Space Committee, Space Science Board, 10 July 1962.

August 1963

National Academy of Sciences
National Research Council
2101 Constitution Avenue, N. W.
Washington, D. C.

S P A C E S C I E N C E B O A R D

Position Paper on Theoretical Aspects of Radiobiology
as Applied to the Space Program

by

The Panel on Radiation Biology
of the
Environmental Biology Committee

Introduction

The Panel* recognizes the need for radiobiological studies of an applied nature with reference to manned-flight programs. It believes, however, that it would be shortsighted for the United States to confine its efforts only to the solution of immediate problems, since in the long run successful exploration of space will be aided by the contributions of basic research.

At the outset the Panel wishes to stress two points: first, that both the immediate biological research program and the continuing program for basic studies should be built upon the large body of existing knowledge of radiation effects; and, second, that the attitude that all radiobiological experiments need be repeated in the space environment should be resolutely rejected.

At the present time, studies on fundamental radiobiology cannot easily be performed in space; it is, therefore, recommended that wherever possible investigations be carried out in ground

* Membership of the Panel and its parent committee is given in the appendix.

laboratories in preference to flying laboratories.

The Panel recognizes that the space environment does vary from the terrestrial environment, but the variations are not so unique as to lead to the expectation of strikingly different effects of radiation in space. It is, however, barely conceivable that radiations whose effects are well known under terrestrial conditions may have some unsuspected biological effects when combined with unusual features of the space environment, e.g. zero gravity. In order to rule out the existence of such effects it is important to design experiments so that any discrepancies between biological effects and physical measurements can be detected with proper statistical precision. This has not been the case in prior radiobiological studies that have depended solely on very low and inaccurately measured doses of ambient space radiation. It has accordingly been difficult to distinguish the observed response levels from random noise, and the experiments have been inconclusive and expensive. The Panel strongly recommends, therefore, that a few simple, but discriminating, experiments be performed to ascertain whether additional experiments in space would have any basic radiobiological interest.

The Panel does not expect that the unusual features of space, such as zero g, will modify radiation effects in any significant way. Any unique types of radiation in space are likely to be too low in intensity and too mixed with other types to lead to meaningful biological results. Experiments in fundamental radiobiology can best be done on Earth. For these and other reasons the Panel does <u>not</u> recommend that space experiments in fundamental radiobiology be assigned a high priority. The experiments are recommended only if they can be done without disturbing more urgent projects and without large expense. They are justified,

not by an expectation of striking fundamental findings, but as insurance against the remote possibility that our negative expectations are wrong.

Physical Studies

Before any well-conceived radiobiological experiments can be performed in space, it is necessary to have information on the temporal and spatial distribution of the radiations to be encountered. Consequently, the efforts being made to obtain the above information by physical means should be encouraged and supported. It should be noted, however, that the factors influencing radiobiological action may not be revealed by experiments designed for purely physical purposes. We recommend, therefore, collaboration between radiobiologists and the physicists concerned with measuring radiation in space to insure that measurements of interest to biologists are made.

Biological Effects of Heavy Ions and Mesons

The biological effects of heavy ions (especially $Z > 2$), mesons, and the long-range effects of low levels of radiation are of specific interest to space radiobiology. There is no doubt that fundamental studies on the biological effects of heavy ions will not only help in the interpretation of radiobiological effects in space, but also contribute to our understanding of biology in general. These effects can be studied to a considerable extent with existing heavy ion linear accelerators such as those at Yale University and the University of California at Berkeley; they cannot be studied in space owing to the low flux of heavy ions and inaccurate dosimetry. On the basis of present-day knowledge, it is possible to calculate the

doses that will be produced by fast delta rays emitted from the tracks of heavy ions traveling at high velocities. Such calculations should be made. In addition, the delta ray clouds surrounding heavy primaries can be simulated by the use of microbeams of protons or electrons. Since relativistic heavy ions produce Cerenkov radiation in the ultraviolet region, the possible biological effects of such radiation should be examined. We also believe that a careful synthesis of the present state of knowledge on the biological effects of heavy ions would be useful.

When heavy cosmic ray particles interact with the shell of a space craft, an appreciable number of mesons will be formed. Mesons, particularly π^- mesons, can release their energy in extremely intense local bursts, and systematic studies on the biological effects of mesons should be carried out; again in laboratories on Earth.

Controlled Radiobiological Experiments in Space

There is the remote possibility that the radiobiological response may be modified by factors as yet unknown and perhaps not susceptible to study terrestrially. Experiments designed to settle this matter must include the exposure of biological materials during space flight and must meet the following criteria of reliability: 1) the use of well known biological systems, e.g., mutation induction or chromosome breakage; 2) the use of a sufficient number of individuals in the experiment to guarantee statistical precision on the results; 3) the exposure of the system to known quantities and qualities of radiation; 4) the use of adequate controls.

An example of a suitable experiment might be the exposure of a stable cell system to known quantities of radiation from an enclosed source while in orbit. A package no larger than a pencil could be designed for such an experiment. The experiment should provide for a graded series of radiation doses to a set of samples completely sealed, so far as possible, against external influences. Such preliminary experiments could be completed within a year.

If the results of such adequately controlled experiments on diverse systems are negative, then the question of the existence of space factors that modify radiobiological principles as we now understand them would be answered in the negative. The further pursuit of such modifying factors would, at this point, no longer exist as a matter of primary practical importance.

Studies on the Ambient Radiation in Space

Only after physical studies have provided sufficient information on the temporal and spatial distribution of radiations of different qualities in space should there by investigations with biological material on the ambient radiations in space to check for effects that are unexpected. For these investigations simple systems are needed that can survive the rigors of space flight without too elaborate environmental control, and that can be measured either automatically in flight or after recovery. Failure of the ambient radiation to produce unexpected results in several systems should lead to de-emphasis of biological experiments in orbit.

If, and only if, the experiments, either with the enclosed source or the ambient radiation, yield results other

than those expected on the basis of existing radiobiological knowledge would additional experiments be indicated. These experiments should attempt to find the cause of any unexpected result so that this factor can be studied in laboratories on Earth rather than in space. The Panel wishes to stress that the initial emphasis should be placed on cellular rather than mammalian systems. It should be noted that the radiobiological reactions of whole mammals are difficult to interpret primarily because of the many uncontrolled variables that must be accepted. The observations, therefore, must necessarily involve large numbers of individuals if the confidence limits of the results are to be narrow; thus an experiment using 100 mice is preferable to one using a single chimpanzee.

Long-Range Considerations--Fundamental Research and Training

In the preceding section, the Panel has considered a number of radiobiological experiments that are related to the clarification of preliminary problems. The success of future, more sophisticated, space ventures, however, is dependent upon the continued development of our fundamental understanding of biology and its related sciences. The support of a broad program of fundamental research, of training, and of the construction and maintenance of research and training facilities is necessary and should be implemented.

The molecular mechanisms underlying the response of cells to radiation are beginning to receive careful analytical attention, and some understanding of the lesions induced in molecules of biological importance is beginning to emerge. Investigation of the nature of these lesions, as well as of the reactions that produce, circumvent, or reverse them will provide insight

into the effects of radiation on organisms. Furthermore, our current understanding of the control of gene action and of the mechanisms by which that action is translated into the complex array of cellular activities is undergoing impressive development. An understanding of these phenomena is basic to an understanding of the interaction of radiation with biological systems. Consequently, the sponsorship of experimental research in the broad area of genetics, microbiology, biochemistry, and biophysics is appropriate to a sustained program in the space sciences.

It also seems likely that a theoretical approach utilizing the emerging information from radiochemistry, radiobiology, biochemistry and genetics would be fruitful. The known physical characteristics of radiation and the known molecular consequences of radiation could be described in terms of hypothesis and used to make predictions regarding their biological effects. The successful development of an inclusive radiobiological theory would be of great help in the designing of experiments to be performed in the environment of space, and would allow a confident approach to almost all radiobiological problems that might be encountered. Since the support of a program of theoretical study is relatively inexpensive as well as timely, the Panel recommends the initiation of such a program.

It should also be pointed out that since the general levels of radiation in space are higher than those found on Earth, there will be continuing interest in such delayed and long-term effects as carcinogenesis and life span reduction.

Study of these problems should be integrated with the activities of other interested groups.

Implementation and Intra-agency Cooperation

Earlier in this report it was emphasized that a broad body of knowledge already exists in the field of radiobiology. This has evolved because of the extensive support of radiation research by the Atomic Energy Commission, the Department of Defense, and the National Institutes of Health. Since the radiobiological issues before the National Aeronautics and Space Administration are, to a large extent, identical to those before the other agencies, the Panel recommends that a strong and continuous liaison be established between the pertinent agencies. This should be implemented in at least three ways: 1) NASA should draw upon the other agencies and their laboratory facilities for advice and assistance; 2) the review committees for extramural research proposals submitted to the NASA should include a monitoring member for each of the other interested agencies; and 3) a radiobiologist should be included on the advisory committees that make periodic erviews for the programs in NASA flight and research centers.

Summary

This report has been concerned with the radiation environment of space and its biological effects. We have outlined experimental areas worthy of immediate attention and long-range programs that should be included in the in the space science effort. Since the appropriate tests need not be elaborate, we have included the search for qualitatively new interactions in space flight as part of our recommendations, although the existence of such interactions is not highly probable.

The specific recommendations fall into four categories;

1) studies in terrestrial laboratories of biological effects of heavy ions and π^- mesons; 2) experiments with enclosed radiation sources to rule out the possibility of unusual interractions of radiations and the space environment; 3) Experiments designed to verify that the effects of the ambient radiation in space are those predicted from existing radiobiological knowledge; 4) the fostering of basic radiobiological training and research.

APPENDIX

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Panel on Radiation Biology

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