N73-19867
CR-128862
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RESEARCH and

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INCORPORATED

LIFE SCIENCES DIVISION

SPECIAL TECHNICAL SERVICES FOR INVESTIGATION OF LIGHT FLASH PHENOMENA

MARCH 1973

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FINAL REPORT

Contract No. NAS 9-12081

National Aeronautics and Space Administration
Manned Spacecraft Center
Houston, Texas

8531 N. NEW BRAUNFELS AVE. • SAN ANTONIO, TEXAS 78217

SPECIAL TECHNICAL SERVICES FOR INVESTIGATION OF LIGHT FLASH PHENOMENA

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APPROVED BY:

James V. Benedict

James V. Benedict, Ph. D.
Manager
San Antonio Branch
Life Sciences Division

SUMMARY

This report describes work performed by the Life Sciences Division of Technology Incorporated to further study and understand the mechanism of the light flash phenomenon observed by astronauts during space flight. The effort reported was conducted under Contract NAS 9-12081 for the Manned Spacecraft Center of the National Aeronautics and Space Administration during the period 1 July 1971 - 1 February 1973.

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1. INTRODUCTION

Although attention has been focused on the light flash phenomenon as a result of early and all subsequent Apollo flights, the potential existence of the problem was recognized over twenty years ago by Professor Cornelius A. Tobias of the University of California at Berkeley. As a result of studies on the radiation hazards associated with manned space flight, Tobias hypothesized that heavily ionized single tracks would appear as small light flashes to a dark adapted individual.[28] The appearance of light flashes was confirmed by astronaut Aldrin during the translunar flight of Apollo 11. Aldrin's colleagues, Armstrong and Collins, reported that they also had detected "streaks" and "points of light." The crews of all subsequent Apollo missions, with one exception, have reported similar "sightings", both with the eyes open and with the eyes closed.

Several theories have been advanced to explain the light flash phenomenon. There is general agreement that the phenomenon may be attributed to penetration of the eye by cosmic particles with retinal stimulation occuring by one of the two mechanisms. One explanation postulates that Cerenkov radiation is responsible for the light observed. A second explanation is that retinal receptors are stimulated directly by cosmic particles, producing phosphenes or sensations of light, either through ionization or excitation.

Cerenkov radiation results from the motion of a charged particle through a transparent medium at a rate which exceeds the velocity of light in that medium. The light observed is frequently attributed to a "shock wave" phenomenon and has been thought of as an optical analog of the sonic boom.[33] Fazio, Jelly and Charman calculated that high energy nuclei with a charge greater than or equal to six are capable of producing Cerenkov light which is comparable to that observed by the Apollo crewmembers.

The hypothesis based on direct excitation of neural tissue is certainly a plausible explanation. Fleisher and Price confirmed that cosmic rays do indeed traverse the astronaut's heads. This was deduced from observations of cosmic ray tracks in the plastic helmets worn by Apollo crewmembers. The hypothesis of neural stimulation assumes that alpha particles or other heavy particles react with the retinal nervous system, possibly the outer rod segment, to produce visual sensation. McMillan, Chapman and Tobias utilized nitrogen ions and personal observations to conclude that accelerated ions do produce visual sensations, but only if they interact directly with the retina. Each of these investigators placed his head in the nitrogen ion beam and wisnessed no visual sensation when the beam was directed through either the anterior chamber of the eye (including the anterior portions of the retina and the vitreous humor) or through the occipital lobe of the brain (where visual signals are processed). However, when the beam penetrated the

posterior portion of the retina, bright streaks were observed. The importance of these nitrogen experiments is that they demonstrate conclusively that Cerenkov radiation is not necessary to explain the flashes, since the ions utilized in the experiment were below Cerenkov threshold. This does not, of course, rule out the possibility of Cerenkov radiation producing visual sensations, it simply demonstrates that other mechanisms are possible. Thus, visual patterns caused by other than Cerenkov effects can most probably be attributed to direct retinal stimulation by atomic nuclei and by charged particles from nuclear reactions involving neutrons.

A continual question that arises in connection with the light flash phenomenon centers around the absence of such observation during the Mercury, Gemini and early Apollo flights. Several explanations have been proposed in response to such questions.

One explanation is that since the intensity of the light flash is proportional to the square of the nuclear charge, and since particles of sufficient charge to produce visual stimulation are absorbed and disintegrated in the atmosphere, they never reach ground-based observers. The vast majority of particles that impinge upon the surface of the earth are singly charged particles such as muons, electrons and protons. These particles do not carry sufficient charge to produce light intensities that would exceed the visual threshold.

Fazio, Jelly and Charman[9] have considered the explanation that the magnetic field of the earth prevents the primary radiation from reaching the earth-orbiting satellites. However, they[9] have demonstrated that Cerenkov radiation of sufficient energy to produce visual sensations can penetrate the earth's magnetic field. They proposed that the astronauts of the early missions either were not dark adapted, were too occupied or did not rest for sufficiently long periods for the appropriate conditions to be realized.

An additional theory which explains the absence of visual "sightings" during earth orbit was explained in a Los Angeles Times - Washington Post News Service article by Thomas O'Toole.[29] In this article it is stated that astronauts in earth orbit flight, such as those aboard the Mercury or Gemini excursions, were protected from cosmic rays by the Van Allen Radiation Belts 10,000 to 25,000 miles from earth. This reasoning also may be applied to the Apollo 7 and Apollo 9 flights. Although the crews of Apollos 8 and 10 engaged in translunar flight, no unusual visual sensations were experienced. This is not unexpected since these astronauts were the first groups to the moon and always kept one man on watch. The cabins, therefore, were never sufficiently darkened to permit adequate dark adaptation and subsequent detection of the light flashes. Thus the first sightings began with Apollo 11 and continued through Apollo 17.

The controversy over which mechanism, Cerenkov radiation or direct neural stimulation, is responsible for the observed effects is a matter of great interest to scientists and has stimulated research by physicists, physiologists and physicians. The major concern, of course, is the assessment of the potential hazards to astronauts on long term missions.

Although Zeevi, Lewis and Tobias [23] have detected retinal degeneration in a mud puppy exposed to a beam of high energy ionized nitrogen, others [29] have hypothesized that even a 200 day mission would produce no detectable decrement in human visual performance. According to their estimates [29], a 200 day mission would result in the destruction of approximately 1.25×10^6 of the 1.3×10^8 receptors in the retina. Since it is estimated that a loss of several percent of one's receptors can occur without a detectable change in visual performance, it is not anticipated that a mission of approximately 200 days duration would result in any serious injury.

In conclusion, it appears that of the two mechanisms proposed, the direct neural stimulation hypothesis provides the more likely explanation of the light flash phenomenon. However, the alternate mechanism, Cerenkov radiation, is certainly plausible and cannot be excluded at this time.

2. WORK PERFORMED

Apollo 11 through 17 crew members have, with one exception, reported being aware of discrete flashes and streaks of light during periods of darkness in spaceflight. These unusual light perceptions were visible with the eyelids open or closed and occurred with a frequency no greater than 1-2 per minute.

The origin of these phenomena is not completely clear and their significance has not yet been ascertained. The physics, physiological optics and neurophysiology of the visual system suggest several possible explanations, some of which suggest benign sources of constituting no danger to the astronaut. Other possible causes are potentially injurious. It is desirable that the orgin of these phenomena be identified.

The work reported herein was undertaken in support of the Preventive Medicine Division of the Manned Spacecraft Center in Houston, Texas. To assist this group in further understanding the mechanism of this phenomenon, Technology Incorporated has performed the following tasks:

1. maintained a file of pertinent literature, reports, references, and reviews,
2. assisted in analyzing and validating the reports and findings obtained from Apollo crewmembers,
3. provided technical assistance in determining fit and measurements of the ALFMED apparatus and headpiece, and
4. assisted in the analysis of the data generated by the study, in the

preparation and dissemination of documentation generated by the technical program, and in the data reduction and clerical work as required.

2.1 Literature Search

A review of the literature pertinent to the light flash phenomenon has resulted in a list of numerous reports, publications and reviews which discuss various aspects of the problem. The bibliography presented in section 3 presents the major articles of interest. Significant conclusions or results reported in many of the referenced articles have already been noted in the introduction.

2.2 Analysis of Apollo Transcripts

To gain further insight into the underlying mechanisms and the factors which are responsible for the spot flashes and streakes of light observed during the translunar flights of Apollos 11-17, members of the Technology Incorporated scientific staff have undertaken an analysis of the voice transcripts of several of the Apollo flights. All statements pertaining to visual illusions and unusual visual phenomena were extracted from the transcripts of Apolls 13, 14 and 15. These transcripts were analyzed to detect basic patterns in either the observations or the reporting of these phenomena. No conspicuous patterns were detected. The condensed transcripts did not produce any further information regarding the light flash phenomenon.

2.3 ALFMED Apparatus

The ALFMED apparatus and headpiece used on Apollo 17 was designed to utilize a moving emulsion to check the direction and speed of particles relative to the eye. Technology Incorporated personnel assisted in the measurements to determine fit of the apparature and studied various devices to position and maintain the apparatus in proper relation to the head. Based on these early studies recommendations were made concerning the fit and positioning of the ALFMED apparatus and headpiece.

2.4 Data Analysis and Documentation

The staff of T. I. have assisted in numerous aspects of data reduction, analysis, preparation and dissemination. This work has included the documentation of reference literature, the transcription of Apollo voice tapes, and the preparation of reports and documents. General clerical support has been provided to the Preventive Medicine Division as required.

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