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REPORT NO.
TDR-69(2260-50)TN-2

Satellite Measurement Program to Determine Ozone Concentration and Albedo in the Near Ultraviolet

SEMIANNUAL TECHNICAL NOTE

(1 January–30 June 1962)

30 AUGUST 1962

Prepared by E. B. MAYFIELD and R. M. FRIEDMAN
Space Physics Laboratory

Prepared for DEPUTY COMMANDER AEROSPACE SYSTEMS
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
Inglewood, California

LABORATORIES DIVISION • AEROSPACE CORPORATION
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Prepared R. M. Friedman
R. M. Friedman
Quantum Physics Department

E. B. Mayfield
E. B. Mayfield, Head
Quantum Physics Department

Approved R. A. Becker
R. A. Becker, Director
Space Physics Laboratory

AEROSPACE CORPORATION
El Segundo, California

ABSTRACT

A flight experiment has been prepared which utilizes a radiometer mounted on an Agena satellite to determine the worldwide distribution of ozone at high altitudes and the ultraviolet albedo in the atmosphere by measuring the transmission and reflection of sunlight at 2550 A. Previous experiments have measured only local concentrations by using radiometers mounted on rocket probes or by measuring sunlight reflected from the Echo satellite. The experimental equipment used and the methods employed to obtain these measurements are discussed in detail. History of the first flight is recorded. A short discussion of the theoretical work is included.

CONTENTS

I.	INTRODUCTION	1
II.	BACKGROUND INFORMATION	1
III	AEROSPACE RESEARCH PROGRAM	2
	A. Experimental	2
	B. Flight History	8
	C. Theoretical	9

FIGURES

1	Ultraviolet Satellite Radiometer	3
2	Response of Typical Ultraviolet Radiometer vs Wavelength	4
3	Field of View Measurement for Albedo Sensor	5
4	Angular Response of Sun-Viewer Light Pipe	6
5	Ultraviolet Radiometer Block Diagram	7

I. INTRODUCTION

The ozone molecule O_3 absorbs strongly in the near ultraviolet between 2000-3000 A. This absorption is a continuum which peaks at about 2550 A. Previous rough measurements by others have indicated the vertical distribution to have a maximum value between 50,000 and 100,000 ft altitude. To date, ozone concentration measurements have been made either with probes or by observing sunlight reflected from satellites. In all cases, these have given only the local concentration. No previous data exist for the worldwide distribution of ozone, its concentration and uniformity.

The experiment currently being performed at Aerospace, using a radiometer on an Agena satellite, will determine the distribution of ozone at high altitudes and the ultraviolet albedo of the upper atmosphere from a study of the transmission and reflection of sunlight in the spectral region centered at 2550 A.

II. BACKGROUND INFORMATION

Johnson et al.[1] have measured the vertical distribution of atmospheric ozone to 70 km altitude using radiometers mounted on rocket probes. Venkateswaran et al.[2] calculated the vertical distribution of ozone from measurements made of the sunlight reflected from the Echo communications satellite and transmitted

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[1] F.S. Johnson, J.D. Purcell, R. Tousey, and K. Watanabe, "Direct Measurements of the Vertical Distribution of Atmospheric Ozone to 70 Kilometers Altitude," J. Geophys. Research, 57, 157-176 (1952).

[2] S. V. Venkateswaran, James G. Moore, and Arlin J. Kreuger, "Determination of the Vertical Distribution of Ozone by Satellite Photometry," J. Geophys. Research, 66, 1751-1771 (June 1961).

through the atmosphere. The results of both measurements are in good agreement and indicate that the ozone has a peak intensity at about 22 km with a particle density of about 2×10^{12} molecules/cm^3. The concentration drops by a factor of 10 at 42 km. The above data were obtained for only a few geographical locations and for a maximum altitude of 70 km.

III. AEROSPACE RESEARCH PROGRAM

The Space Physics Laboratory of Aerospace Corporation has prepared a flight experiment for an Agena satellite to measure the sunlight transmitted through the atmosphere and the earth's albedo in a spectral region at the center of the ozone absorption band at 2550 A. The satellite is attitude-controlled to within ±3 deg by means of horizon sensors and gas jets so that the same side is always facing the earth.

A. EXPERIMENTAL

The experiment has been designed to determine the albedo (the ratio of reflected to incident light) in a spectral band centered at 2550 A. In addition, the concentration of ozone at high altitudes will be determined from the attenuation of the solar ultraviolet radiation passing through the atmosphere.

These measurements are obtained simultaneously with two sensors (see Fig. 1) each employing ASCOP 541F solar blind photomultipliers. Seven-stage tubes are used in the sun viewing sensor instead of the conventional fourteen-stage tubes because of the much greater signal intensity. These ASCOP tubes have peak quantum efficiencies ranging from 4.9 to 9.5 per cent measured at 2537 A.

Narrow-band Baird-Atomic interference filters, with a peak third-order transmission of about 5 per cent centered at 2550 A, are used to define the spectral region. A 1/8 in. thick $NiSO_4$ filter (opaque between 3400 and 4300 A)

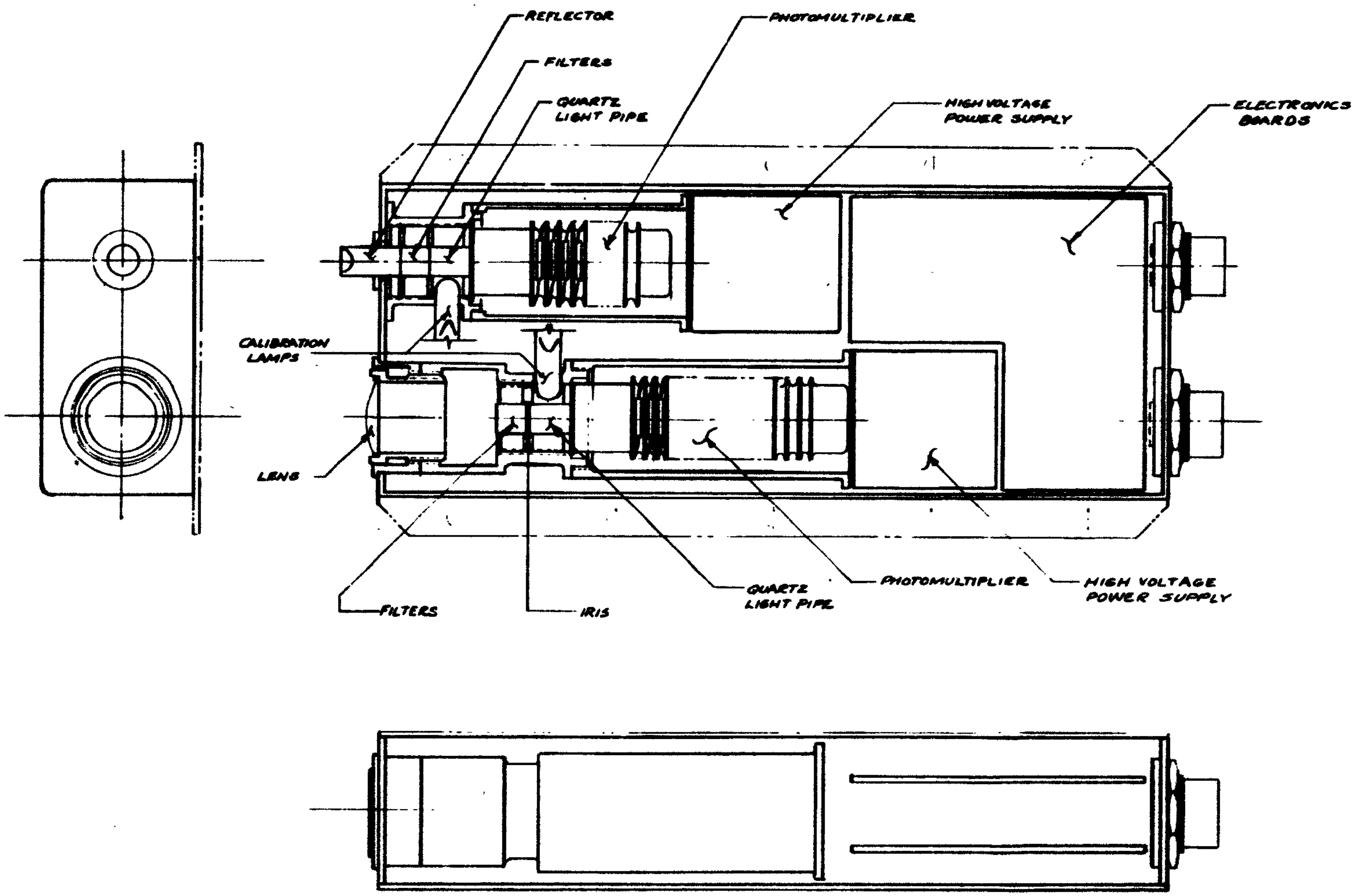

Fig. 1. Ultraviolet Satellite Radiometer

is used to absorb the light from the second-order transmission peak at 3700 A. In addition, a third filter composed of cation X, 2.7 dimethyl - 3.6 diazocyclo-heptic - 1.6 diene perchlorate, in a polyvinyl alcohol film,* was employed to absorb light between 2900 and 3400 A. The thickness of this filter varied between different samples from 7 to 9 mils. The wavelength response of a typical system composed of filters and photomultiplier tube is shown in Fig. 2. This curve was obtained by folding together the measured response for each component.

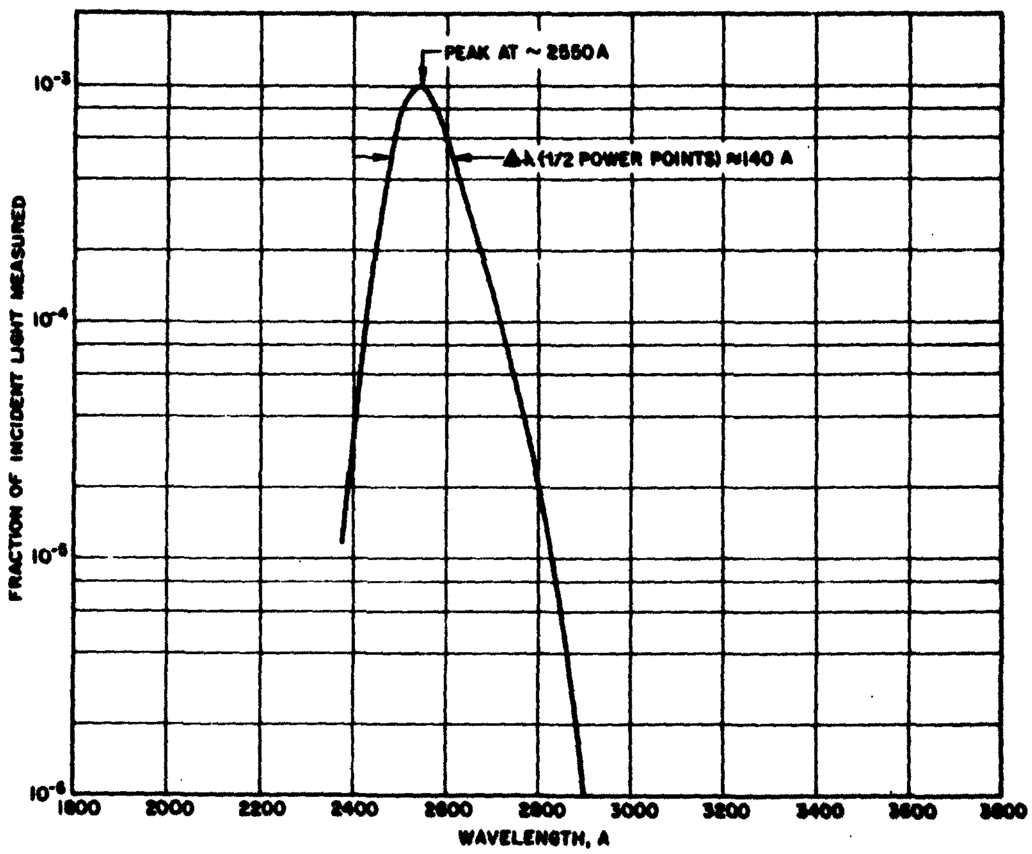

Fig. 2. Response of Typical Ultraviolet Radiometer vs Wavelength (Filter Transmission and Tube Response)

*Dr. William McBride of the U. S. Naval Ordnance Test Station, China Lake, California, supplied us with a sample of cation X.

To determine the albedo, a field of view of 0.7 deg from the top of the atmosphere is observed with one photomultiplier. This is accomplished by use of a lens plus an iris with a 15 mil aperture (see Fig. 1). This defines a region of about 2 mi in diameter at the surface of the earth. The measured field of view of the detector is shown in Fig. 3.

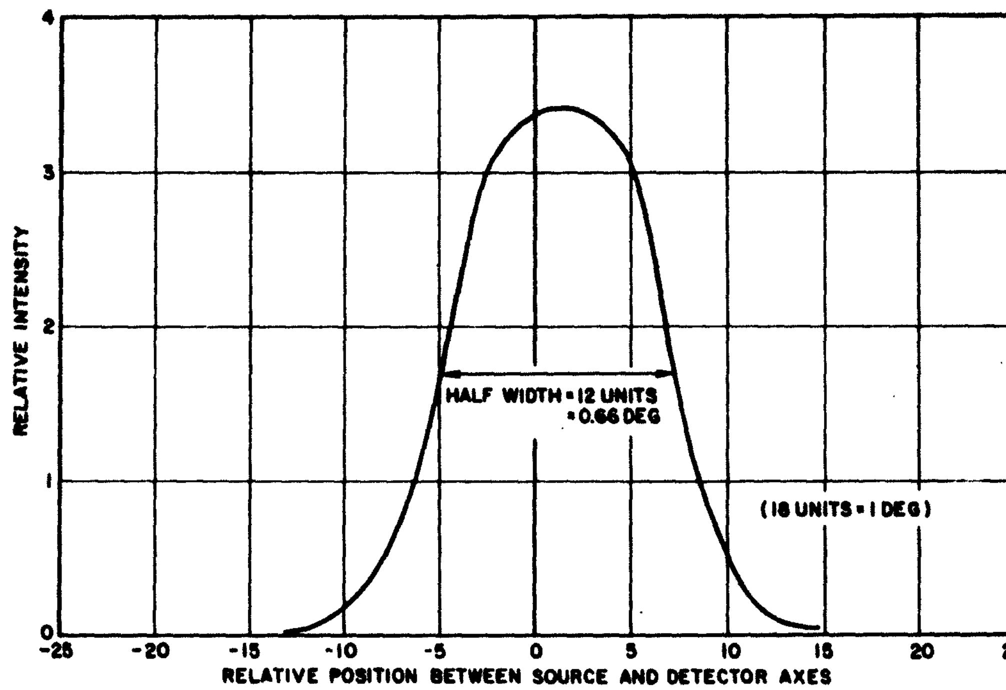

Fig. 3. Field of View Measurement for Albedo Sensor (Detector No. 6)

To observe the transmitted sunlight through the atmosphere, a reflecting hemisphere is located at the end of a quartz light pipe in the optical path of the second photomultiplier. This enables sunlight, entering the rod from the side through an azimuthal angle of 360 deg, to be scattered into the detector. In this fashion, sunlight is observed obliquely through the atmosphere at both sunrise and sunset for the satellite. As the rays pass through denser regions of ozone, the signal is rapidly attenuated from the value in full sunlight to the background level. It has been estimated that with this technique the ozone concentration can be measured down to heights of 45-50 km. A cap has been placed over the end of the quartz light pipe to prevent scattered light from getting into the detector. Also, the upper part of the light pipe has been blackened. The angular response of this system has been measured and is shown in Fig. 4. In the flight experiment, the angle of the sunlight will vary from normal incidence to 15 deg below normal. The data show that the response is reasonably uniform over this range.

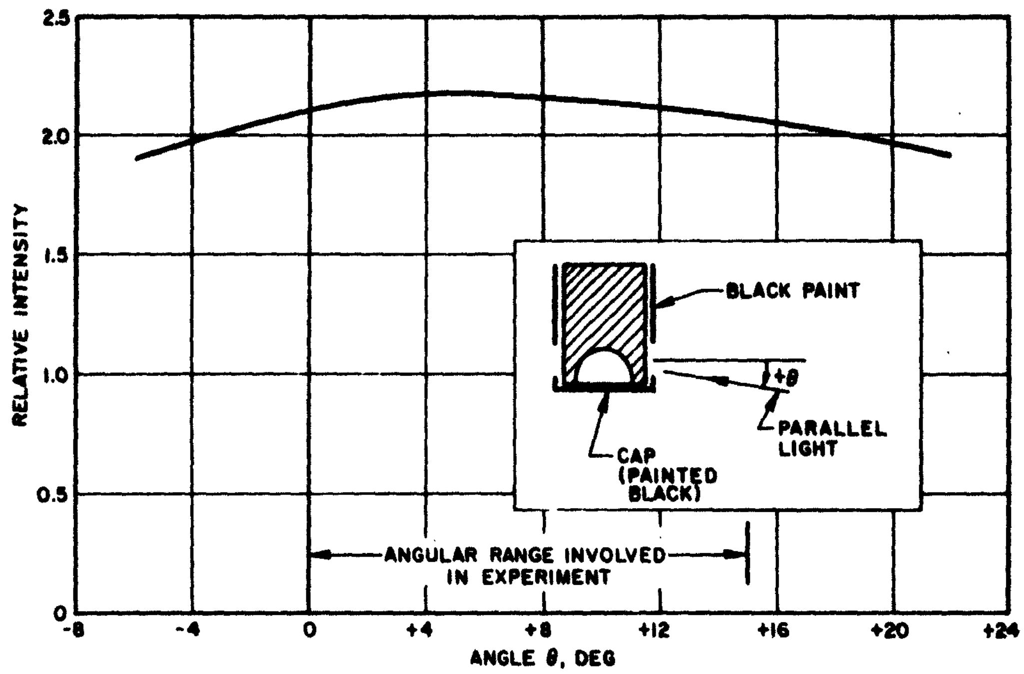

Fig. 4. Angular Response of Sun-Viewer Light Pipe

The outputs of the sensors are fed into the FM-FM telemetry system supplied by Lockheed and must be expressed in analog form with voltage varying from 0 to 5 v. In order to obtain a wide dynamic range (better than 10^3), logarithmic amplifiers were employed. A block diagram of the system is shown in Fig. 5.

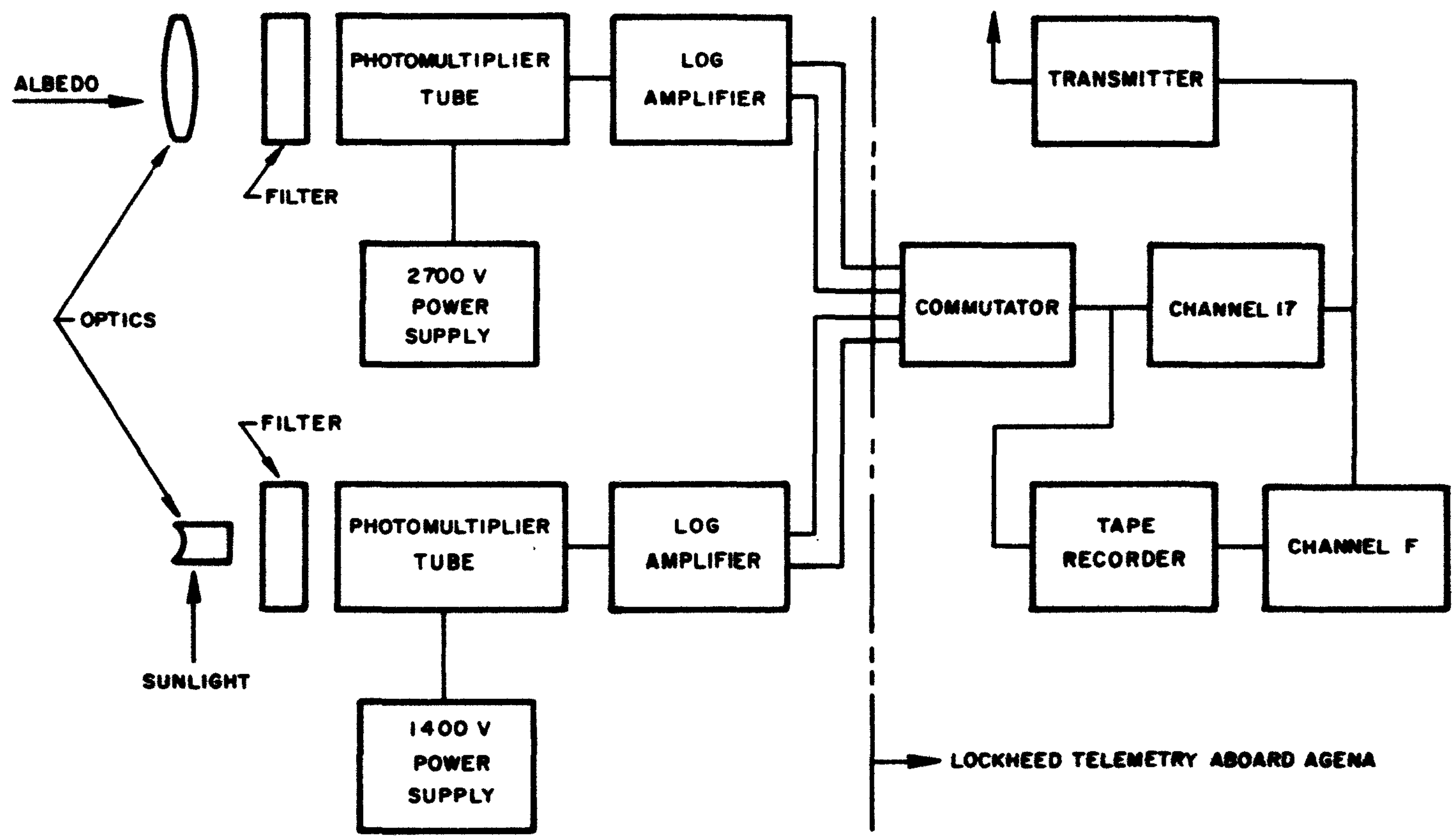

Fig. 5. Ultraviolet Radiometer Block Diagram

The outputs of the albedo sensor are sampled three times a second and the sun viewing sensor 12 times a second. This is accomplished by feeding the outputs to a 60-point commutator which rotates once per second. Other points on the commutator contain sync pulses, calibrations, and vehicle time. The output of the commutator is stored on a tape recorder which is played back during each readout cycle over one of the Air Force tracking stations. In addition, the output of the commutator is read out in real time. In this fashion, a continuous record of the output of the experiment is obtained during the active lifetime of the satellite.

The albedo channel was calibrated in the laboratory using an NBS-calibrated tungsten light source which produces a continuum. Each sensor contains two logarithmic amplifiers with dynamic ranges of 10^2 which are stacked so that a total dynamic range of better than 10^3 is obtained. Calibration curves were obtained with the radiometer in a temperature chamber over a range from 0 to +100°F.

The sun viewing channel (lower in sensitivity by about a factor of 10^4 compared to the albedo channel) was calibrated using a mercury light source which produces an intense line at 2537 A. The mercury lamp was intercalibrated with the tungsten lamp.

B. FLIGHT HISTORY

The first flight radiometer was flown on an Agena satellite launched from PMR at 12:40 pm PDT on 15 May 1962. The vehicle was placed in a polar orbit with apogee 404 mi, perigee 185 mi, and a 94-min period. The experiment operated successfully for the first day of the flight when a failure occurred in the telemetry link and transmission ceased. Quantitative flight data plus orbit parameters have just been obtained from Lockheed, and analysis is proceeding.

The second flight radiometer is scheduled to be launched from PMR in July, and a third one will be flown late in October 1962.

C. THEORETICAL

The equations for determining the ozone concentration from direct measurements of the transmitted intensity of sunlight have been derived. These equations have been programmed for reduction on an IBM 7090, assuming a standard transmission law based on particle density. Single-scattering corrections will be calculated and applied to the data to take account of Rayleigh scattering from the atmospheric constituents. Preliminary calculations indicate that the multiple scattering correction is negligible.

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