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AIRBORNE OBSERVATIONS OF ASTRONOMICAL OBJECTS

FINAL REPORT

NASA Research Grant NGR 02-001-106

May 1976

GEOPHYSICAL INSTITUTE
UNIVERSITY OF ALASKA
FAIRBANKS, ALASKA 99701

Prepared for

NASA/Ames Research Center
Airborne Science Office
Moffett Field, California 94035



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FINAL REPORT

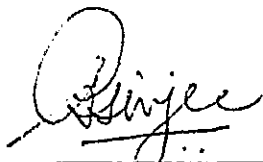
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Principal Investigator

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SUMMARY

During the months of December 1973 and January 1974, the Geophysical Institute of the University of Alaska participated in NASA's airborne mission to study Comet Kohoutek and to simulate space shuttle conditions on the CV 990 as part of the ASSESS program. An optical system, consisting of a heliostat and an 8" aperture f/7 spherical mirror, was employed aboard the CV 990 to image any object in the sky, visible through the aircraft window, on the entrance slit of a half-meter Ebert spectrophotometer which scanned between 3000 and 3570 Å. The principal aim of the experiment was to study the distribution of OH radical in the comet by monitoring the 3020-3090 OH (0,0) band emissions at airplane heights where atmospheric extinction of this radiation is less than at ground level. Unfortunately, the comet turned out to be orders of magnitude less bright than had been predicted by various scientists and much too weak to track with our optical system. Hence, we invested most of our efforts in monitoring the UV spectra of the Sun, Venus and Jupiter. These spectra, as well as the differences and ratios of planetary and solar spectra, are presented. The results indicate that SO, SO₂ and ClO₂ may be present in Venus atmosphere, and Formaldehyde (CH₂O) and C₂O₂ on Jupiter. The solar UV measurements have been analyzed to deduce ozone concentration in the earth's atmosphere.

INTRODUCTION

In 1973, various scientists had predicted that during its closest approach to the sun, Comet Kohoutek would attain a brightness equivalent to a stellar object of visual magnitude -10. For such a bright comet it appeared feasible to undertake airborne optical studies in the ultra-violet which would contribute to our understanding of comet composition and the dynamical processes leading to the vaporization of the relatively dense comet head to form the long, tenuous comet tail. The Geophysical Institute of the University of Alaska proposed to NASA to fly an optical system on the CV 990 to monitor the OH UV emission from various sections of the comet. This optical system was designed to track stellar objects of visual magnitude zero and brighter. Comet Kohoutek never attained the predicted brightness; it was a visual magnitude +4 object at its closest approach to the sun. Since our optical system was not designed for tracking such a faint object, we took advantage of the airborne optical set up to monitor the UV spectra of the Sun, Venus and Jupiter. The results of these measurements are presented in the following sections.

In addition to studying astronomical objects, a section of the airborne mission was aimed at simulating some space shuttle conditions for operating scientific experiments. Details and evaluation of these simulations have been documented by NASA in its report of the ASSESS section of this airborne mission. Our feelings on the relationship of the airborne Science Program to space shuttle requirements was expressed in an invited talk by one of us (GJR, Appendix), at the Payload Operation Crew Function Workshop at L.B. Johnson Space Center on April 16, 1974.

EXPERIMENTAL SET UP

Schematic representation of the optical and electronic systems, employed on the CV 990 for UV studies, is shown in Figure 1. A two-dimensional gyro-stabilized heliostat, mounted near a 14° passenger window, made from UV grade quartz, was used to manually track an astronomical object lying at an elevation between 15 and 30°. This object was imaged on the entrance slit of a half-meter Ebert spectrophotometer by an f/7 spherical mirror of 8" clear aperture. A plane mirror was attached in the spectrometer's slit plane around the entrance slit and a camera, aimed at this mirror, recorded the astronomical objects imaged around the entrance slit. The spectrometer employed a 2-inch square plane grating having 1200 grooves/mm and blazed around 4500 Å. An EMI S-5 UV photomultiplier tube (PMT), cooled with dry ice, was used to detect light; it was operated in an analogue mode. A sine-bar in the grating drive system ensured a linear scan in wavelength.

The spectrometer was operated to scan from 3000 to 3570 and down to 3000 Å again in 25 seconds. A Corning 7-54 glass filter was placed at the exit slit to minimize scattered light contamination in the desired wavelength signal. The photomultiplier tube was operated around 700 V (gain $\sim 10^5$); its dark current at this voltage was about 10^{-11} amps. The analogue signal from the PMT was fed into a Keithley amplifier, which provided a signal between 0 to 10 V for an input between 0 and 10^{-8} amps. The voltage signal from the amplifier together with a fiducial mark from the grating drive system to indicate the reversal in the direction of grating rotation, and a DC level-shift slow time code were recorded on an analogue tape recorder as well as on a Brush chart

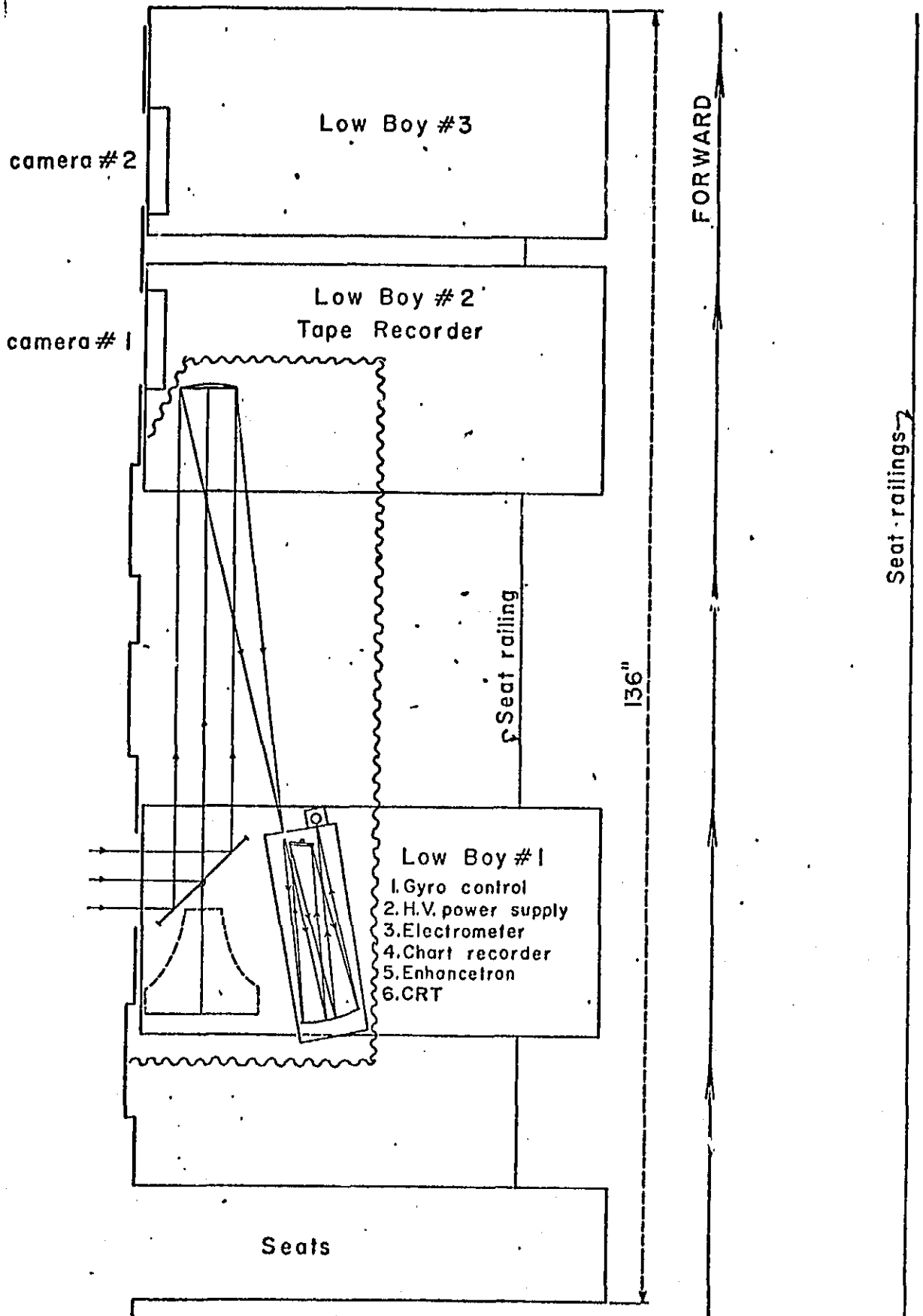


Figure 1

recorder. The fiducial step voltage was also used to trigger a CAT signal average having 400 memory locations in which the PMT signals were summed.

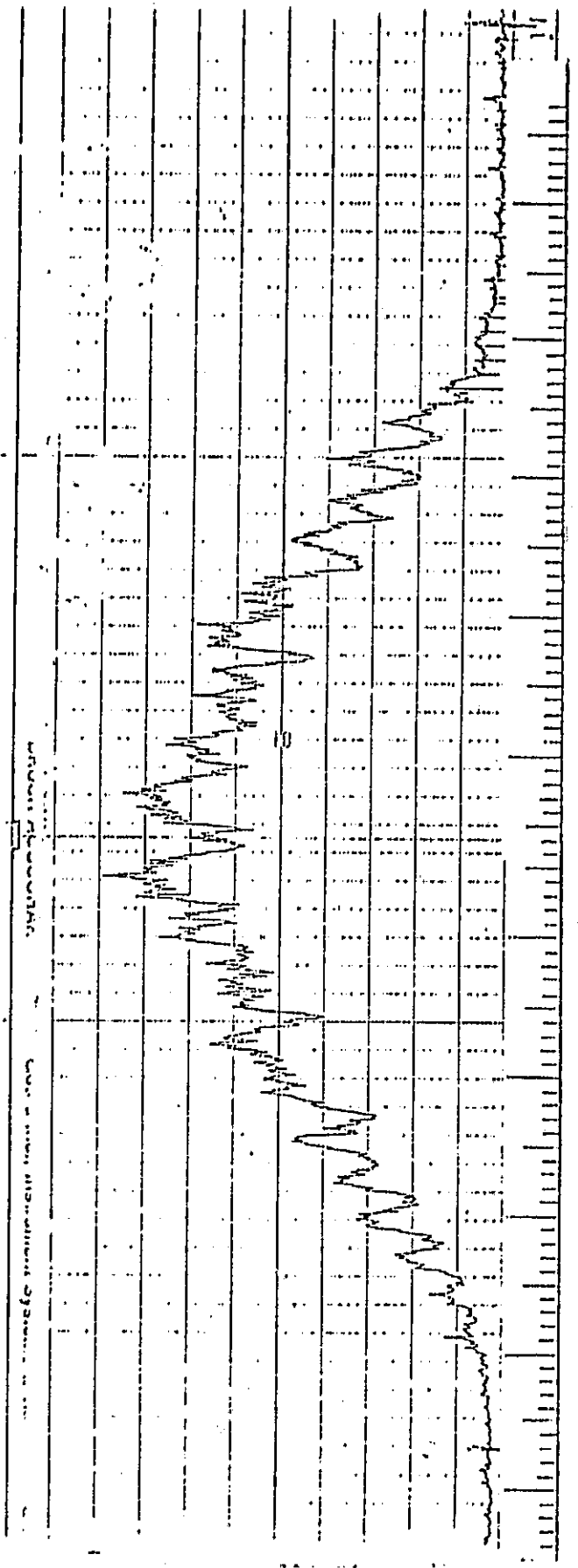
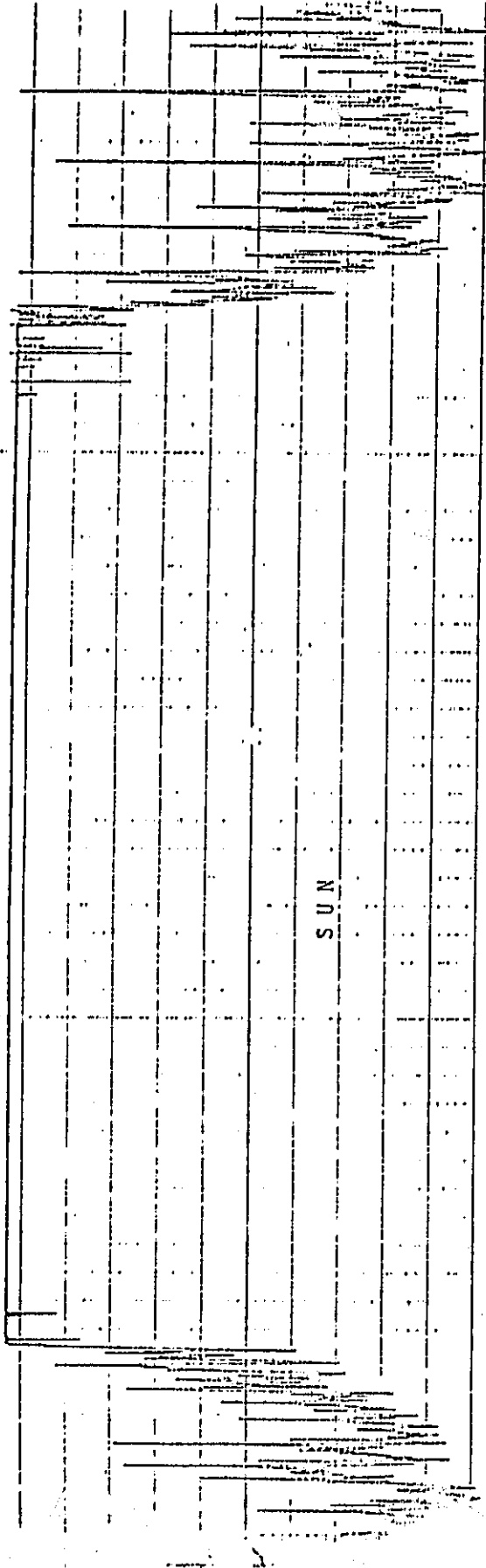
MEASUREMENTS

Concerted efforts were made on all airplane flights to image Comet Kohoutek on the spectrometer slit. However, because of the tremendous problems encountered in manually acquiring and tracking a very faint (visual magnitude $\sim +4$) object, we cannot be certain that at any time the comet was within the spectrometer's field of view over one complete scan period of the spectrometer. We have examined spectral records which were taken at the time when, according to our best judgement, the comet might have been around the entrance slit. In comparing these with scans taken when we are certain the comet was not in the spectrometer's field of view, we see no obvious differences that can be attributed to emissions from the comet.

Manually tracking Venus (visual magnitude -2) and Jupiter (visual magnitude zero) was relatively much easier. Several UV spectra of these planets in the wavelength range 3035 to 3570 A were obtained at about 7 A resolution at 12 km aircraft height. UV spectra of direct and scattered sunlight at the same resolution were also recorded. In addition, we monitored the solar spectrum between 3035 and 3570 A at various resolutions, ranging from 5 A down to about 0.5 A.

Figures 2, 3 and 4 show the raw scans of UV spectra of sunlight scattered in the earth's atmosphere and that reflected from the planetary discs of Venus and Jupiter; four such spectra for each of the planets and the sun were summed separately.

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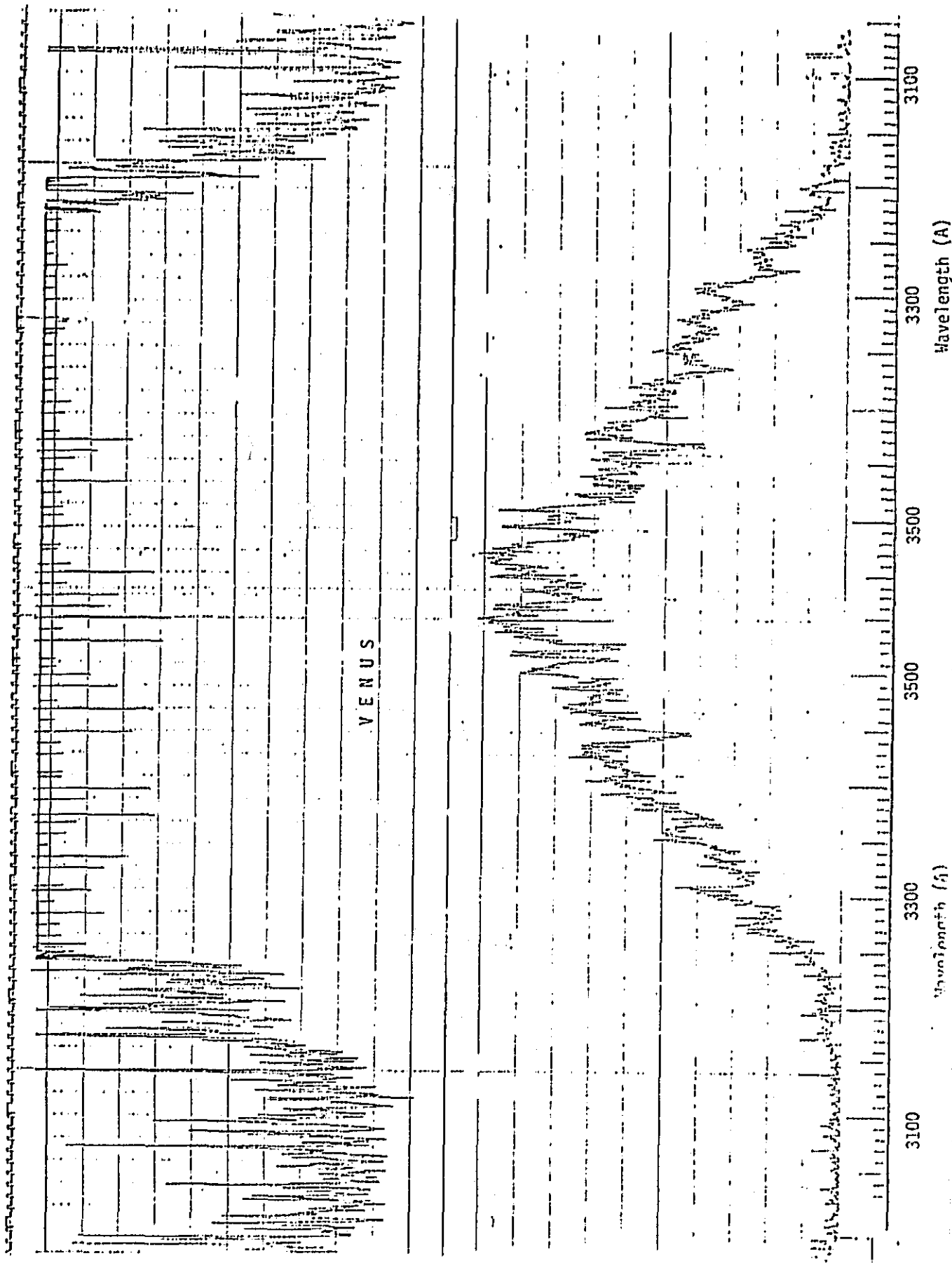


Figure 3

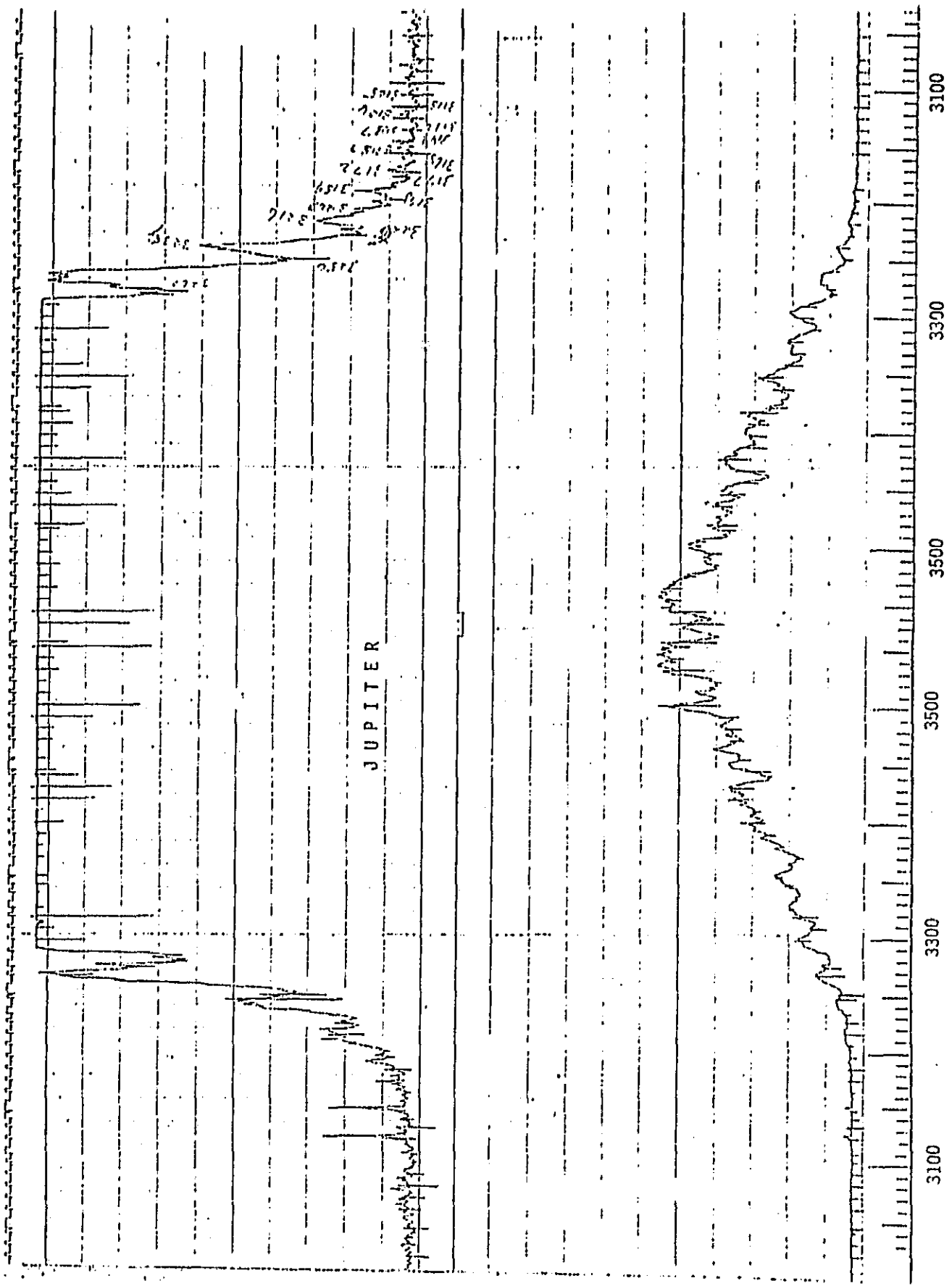


Figure 4

ANALYSIS

The object of planetary UV observations was primarily to obtain some information about the atmospheres of Venus and Jupiter. In principle, this can be accomplished by identifying spectral signatures (mostly in absorption and perhaps through a few emissions) of the atmospheric constituents in the UV light from the planets reaching the earth. Unfortunately, the spectral features contained in the optical radiation received from the planets represent the sum of various effects, not all of which originate in the particular planetary atmosphere of interest. Basically, the light received from the planet, in the line of sight from the aircraft to the planet, represents a portion of solar radiation that has been scattered by the planetary atmosphere and reflected by the planetary surface. As the solar radiation penetrates the planetary atmosphere it is partially absorbed at certain wavelengths, characteristic of the atmospheric constituents, and uniformly re-radiated. The solar radiation is also scattered by an amount which varies with wavelength. When the solar radiation finally reaches the planetary surface the wavelength dependent reflectivity of the surface further modifies the spectral distribution of the solar radiation. The radiation reflected from the planetary surface then undergoes further atmospheric absorption and scattering as it penetrates the planetary atmosphere on its way out to space. This highly modified solar radiation is what reaches the earth where in passing through the earth's atmosphere it is partially absorbed, at certain wavelengths, and scattered by constituents of the terrestrial atmospheres. Hence, the spectral signatures contained in this light pertain both to the atmospheres of the

planet observed as well as the earth. Additionally there are other complicating spectral features, the solar Fraunhofer absorption lines. Consequently a large number of spectral features are present in the light received from a planet, leading to serious overlap of spectral signatures due to the different sources. Moreover, the intensity of the solar UV radiation is not uniform at all wavelengths but has a distribution akin to radiation from a blackbody operating around 5500°K. Hence, the UV light received from a planet at airplane altitudes has the following spectral characteristics:

- 1) Spectral form approximating black body radiation.
- 2) Fraunhofer absorption lines.
- 3) Absorption features characteristic of the constituents of the planetary atmosphere.
- 4) Perhaps a few emission features characteristic of the constituents of the planetary atmosphere.
- 5) Scattering by the planetary atmosphere.
- 6) Differential reflectivity of the planetary surface.
- 7) Telluric absorption features.
- 8) Perhaps a few telluric emission features.
- 9) Scattering by the terrestrial atmosphere.
- 10) Spectral responsivity of radiation detection system.

Our main interest is to identify (3) and to a lesser extent (4), (5) and (6). Hence, effects due to (1), (2), (7), (8), (9) and (10) must be corrected for. The most direct method to accomplish these corrections is to subtract the UV spectrum of direct solar radiation monitored under conditions identical to those in which the planetary measurements were

made. Hence, solar UV spectra were obtained when the sun was at the same elevation as were the planets during the planetary observations. The detectors were operated in identical configuration and resolution and at the same altitude on the airplane. Next we identified a short wavelength range (around 3540 Å), in both the planetary and solar UV spectra, which is relatively free of absorption features and computed the ratios $\alpha_1 = I_\lambda(\text{sun})/I_\lambda(\text{Venus})$ and $\alpha_2 = I_\lambda(\text{sun})/I_\lambda(\text{Jupiter})$ for this small wavelength region. Here I_λ stands for the average signal from our detector when monitoring radiation, at wavelength λ (≈ 3540 Å), from a particular source. The intensity of UV spectrum of Venus was then scaled up by α_1 at all wavelengths. The Jupiter spectrum was similarly scaled by a factor α_2 . These normalized spectra, showing the same signal strength around 3540 Å in both the solar and the planetary measurements, are displayed in Figures 5, 6 and 7.

Figure 8 shows the difference between the spectral measurements of UV light received from Venus and directly from the sun. This difference spectrum represents the effects due to absorption and scattering by the Venus atmosphere surface. A similar plot for Jupiter is shown in Figure 9. Figure 10 shows the difference between the normalized spectra of Jupiter and Venus.

An alternate method of displaying spectral differences presented above involves taking spectral ratios. A direct ratio of normalized spectra suffers from excessive noise introduced by marked variation with wavelength in the intensity of the UV spectra. Hence, variations due to instrumental noise and photon statistics are magnified in the ratios of low level signals while the ratios of stronger signals all tend to

SUN ALONE

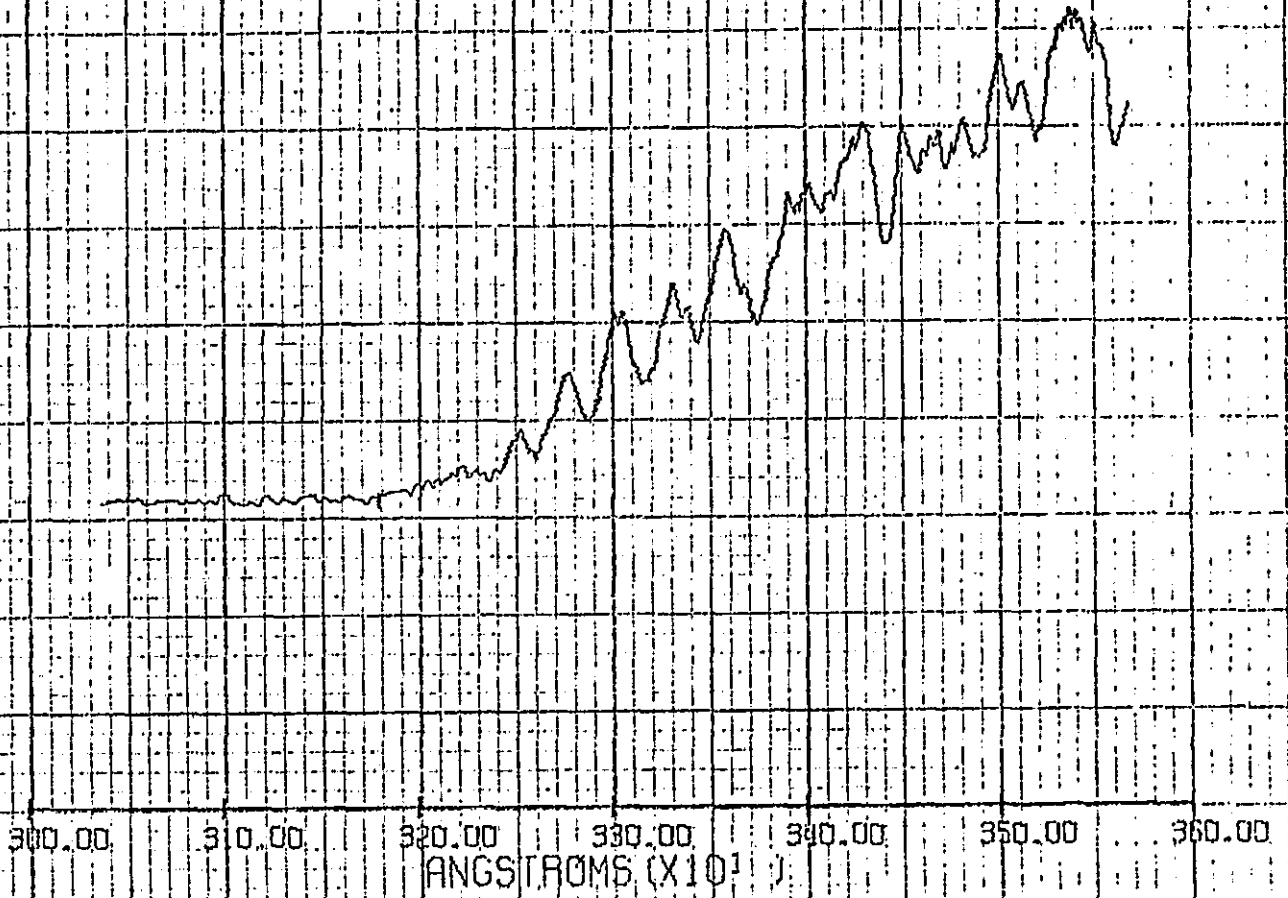


Figure 5

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VNS ALONE

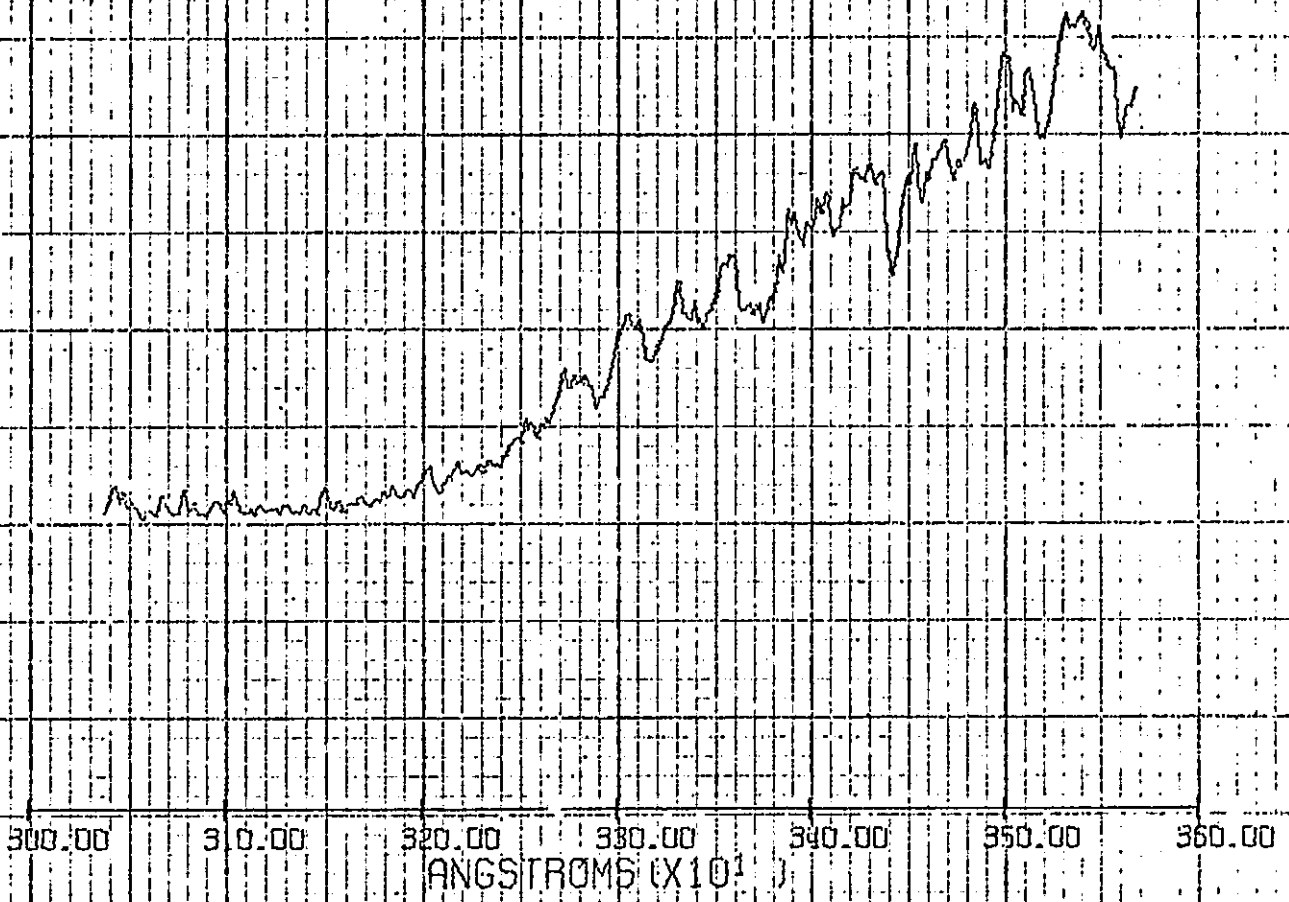


Figure 6

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ANGSTROMS (X10¹⁰)

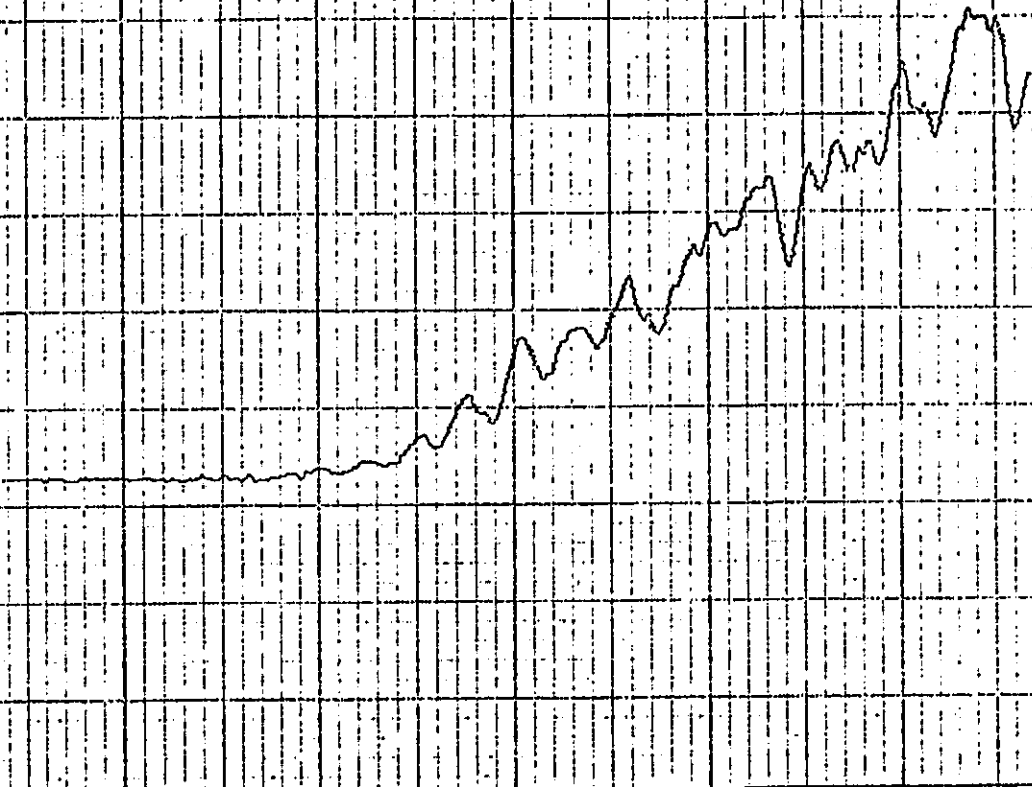


Figure 7

VNS - SUN

NH
ClO₂
CH₂O
SO

300.00 310.00 320.00 330.00 340.00 350.00 360.00
ANGSTROMS (X10¹)

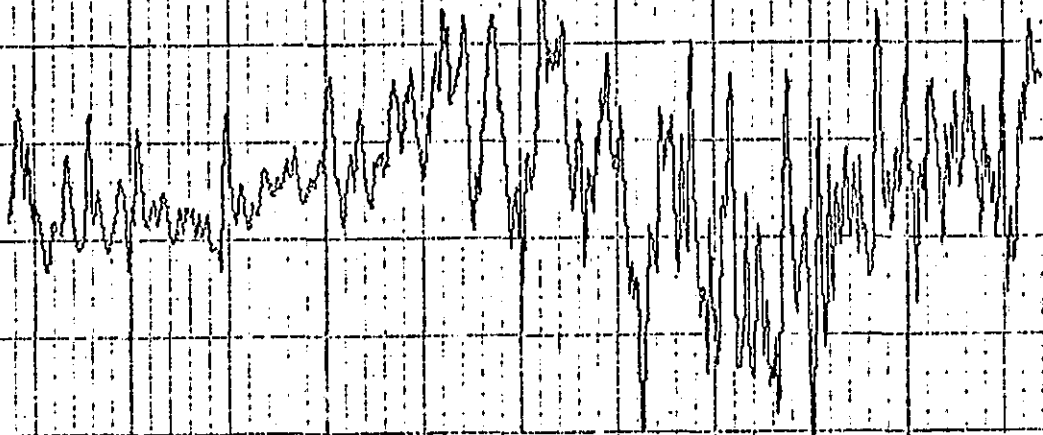


Figure 8

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JPT - SUN

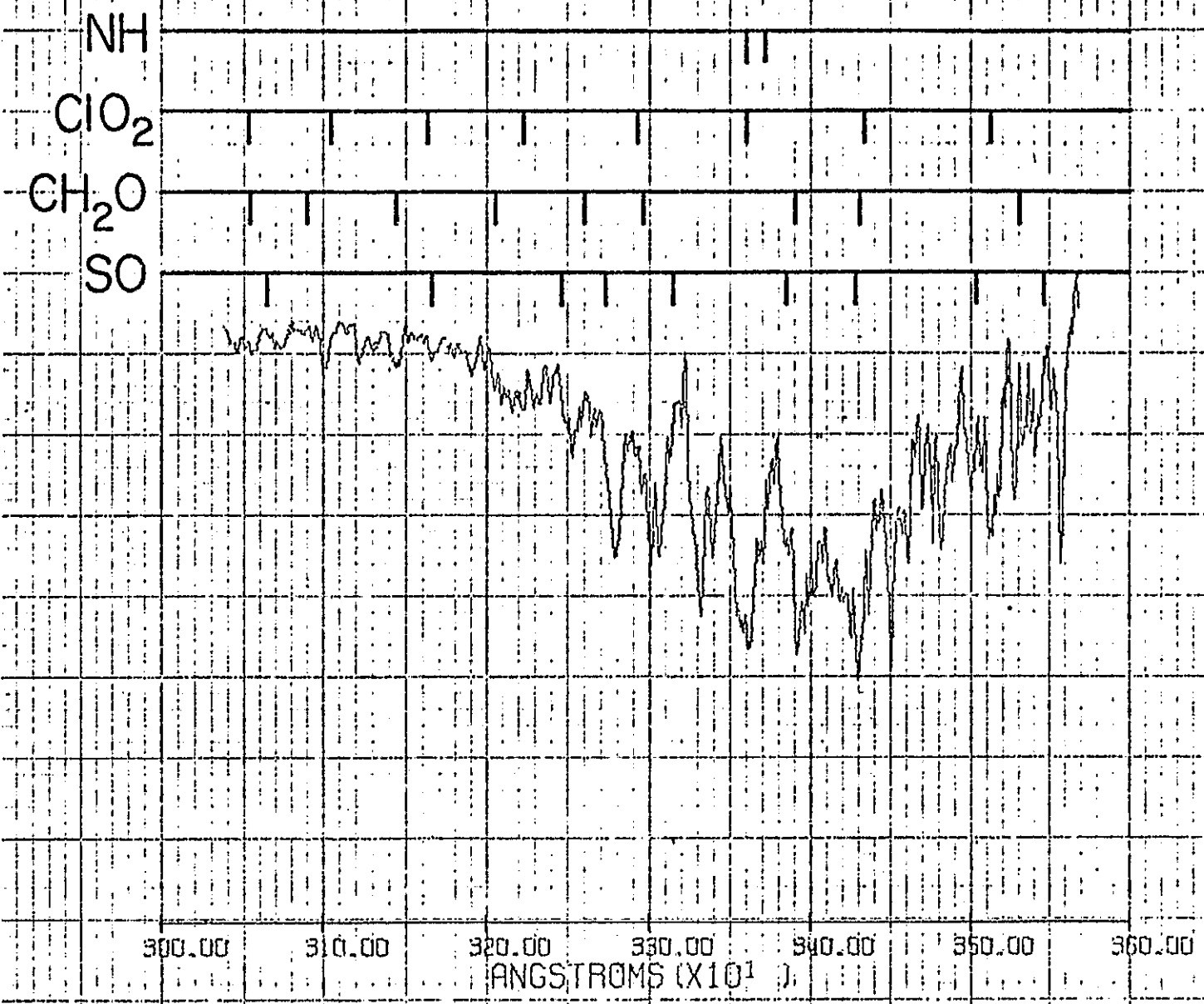


Figure 9

UPT - VNS

NH

ClO₂

CH₂O

SO

300.00 310.00 320.00 330.00 340.00 350.00 360.00
ANGSTROMS (X10¹⁰)

Figure 10

cluster around unity. This is clearly demonstrated in Figures 11, 12 and 13 which show the ratios of normalized planetary and solar spectra. This limitation in the ratio technique can be circumvented by a judicious choice of baseline which makes the ratios at all wavelengths approximately the same and plotting them on an expanded scale to magnify the small differences in these ratios. When this is done, the ratio technique yields information very similar to that obtained from the method of spectral differences, as can be verified by comparing the ratios shown in Figures 14 to 16 with the differences displayed in Figures 8 through 10.

The solar UV measurements themselves can be analyzed to yield some information about the constituents of the terrestrial atmosphere. One such constituent which strongly absorbs solar radiation in the near UV is ozone (O_3). The total concentration of ozone can be determined by matching spectroscopic measurements with synthetic spectral profile of solar UV radiation constructed with various amounts of ozone absorption and corrected for Rayleigh scattering. We have used Arvesen et al's. (1969) measurements of extraterrestrial solar spectral irradiance, Vigroux's (1955) ozone absorption coefficients and Elterman and Toolin's (1965) determination of Rayleigh optical thickness of the atmosphere. The path length along line of sight for solar UV in air and in ozone were calculated using the model atmosphere, appropriate for the location and time of our solar UV measurements ($\lambda = 30^\circ N$, January), listed in U.S. Standard Atmosphere, supplement 1966, and the ozone altitude profile developed by Elterman and Toolin (1965) from ozonesonde network.

VNS X SUN + 0

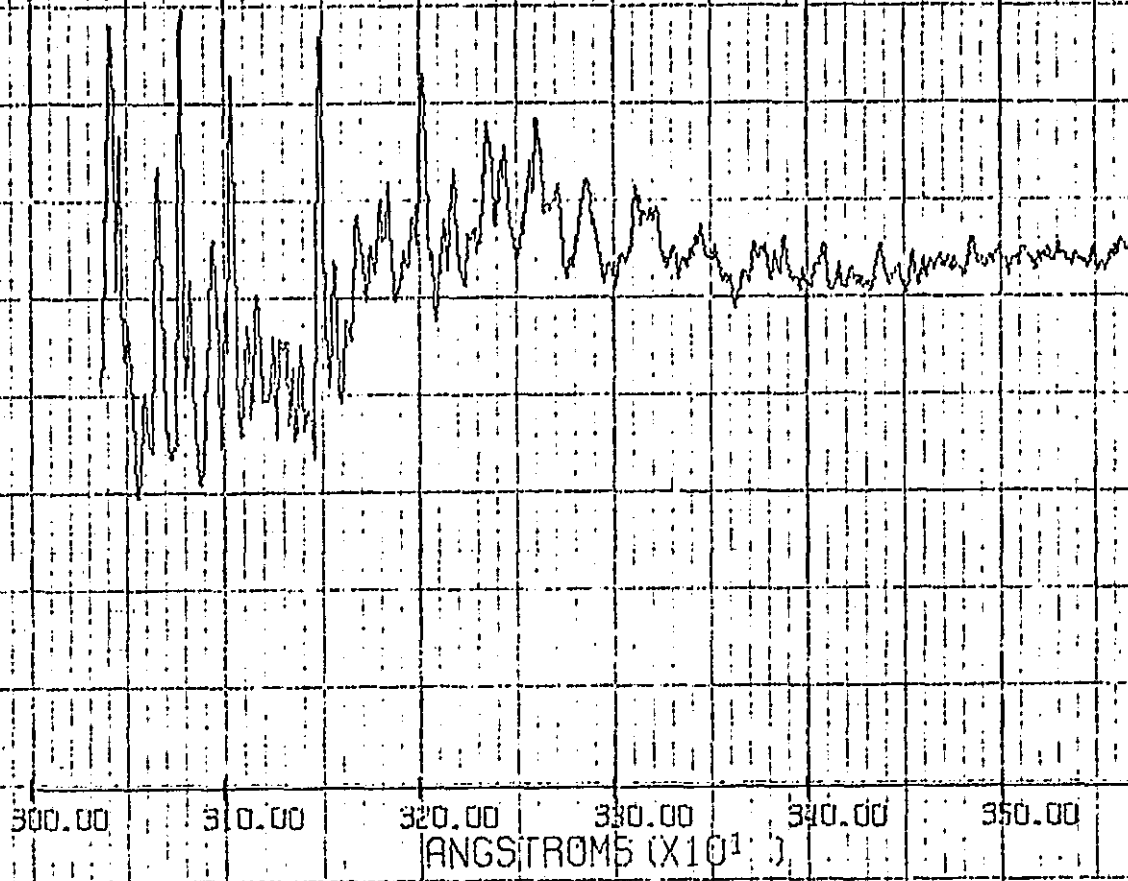


Figure 11

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UPT / SUN + 0

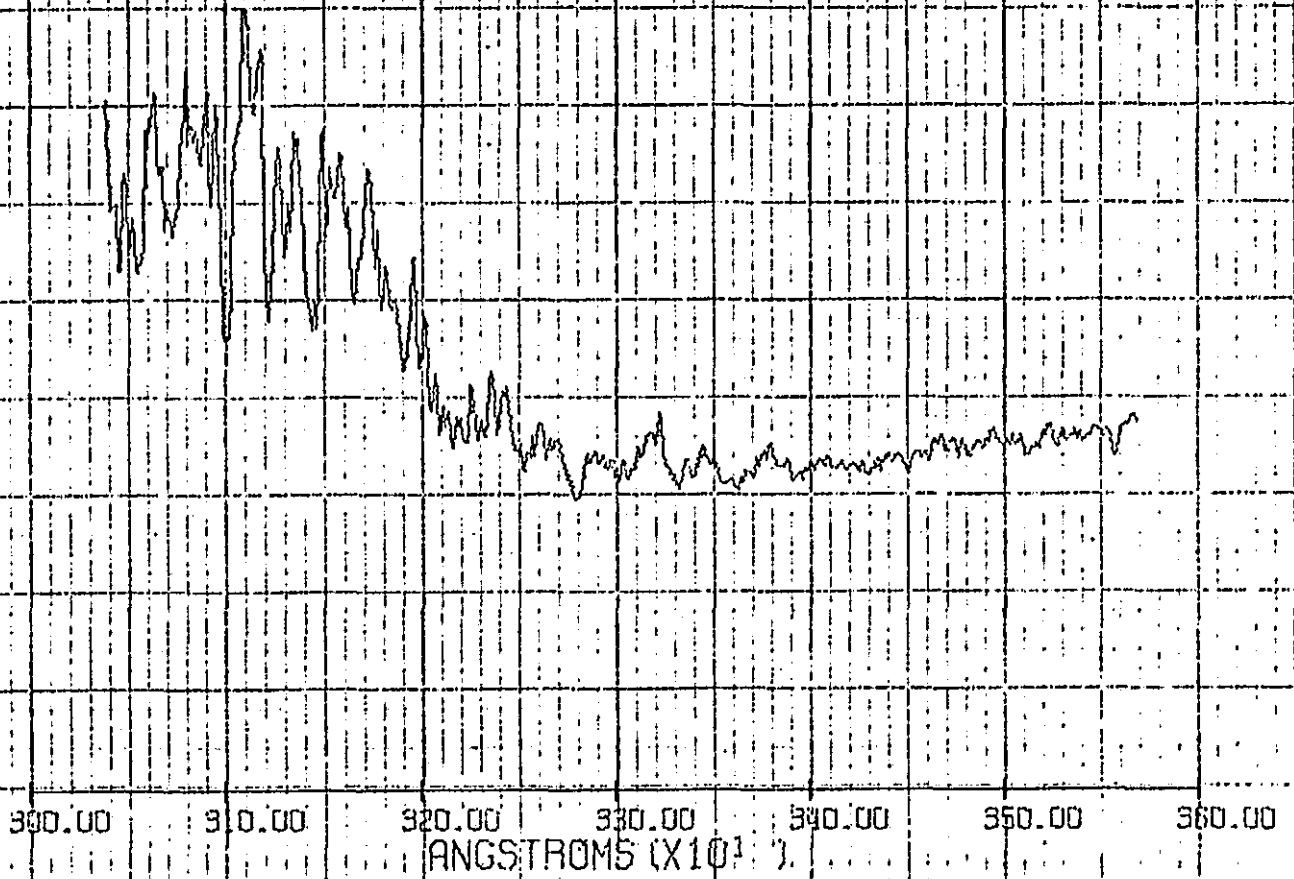


Figure 12

JPT / VNS + 0

300.00 310.00 320.00 330.00 340.00 350.00 360.00
ANGSTROMS ($\times 10^1$)

Figure 13

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VNS / SUN + 800

500.00 510.00 520.00 530.00 540.00 550.00 560.00
ANGSTROMS (X10¹)

Figure 14

JPT / SUN + 800

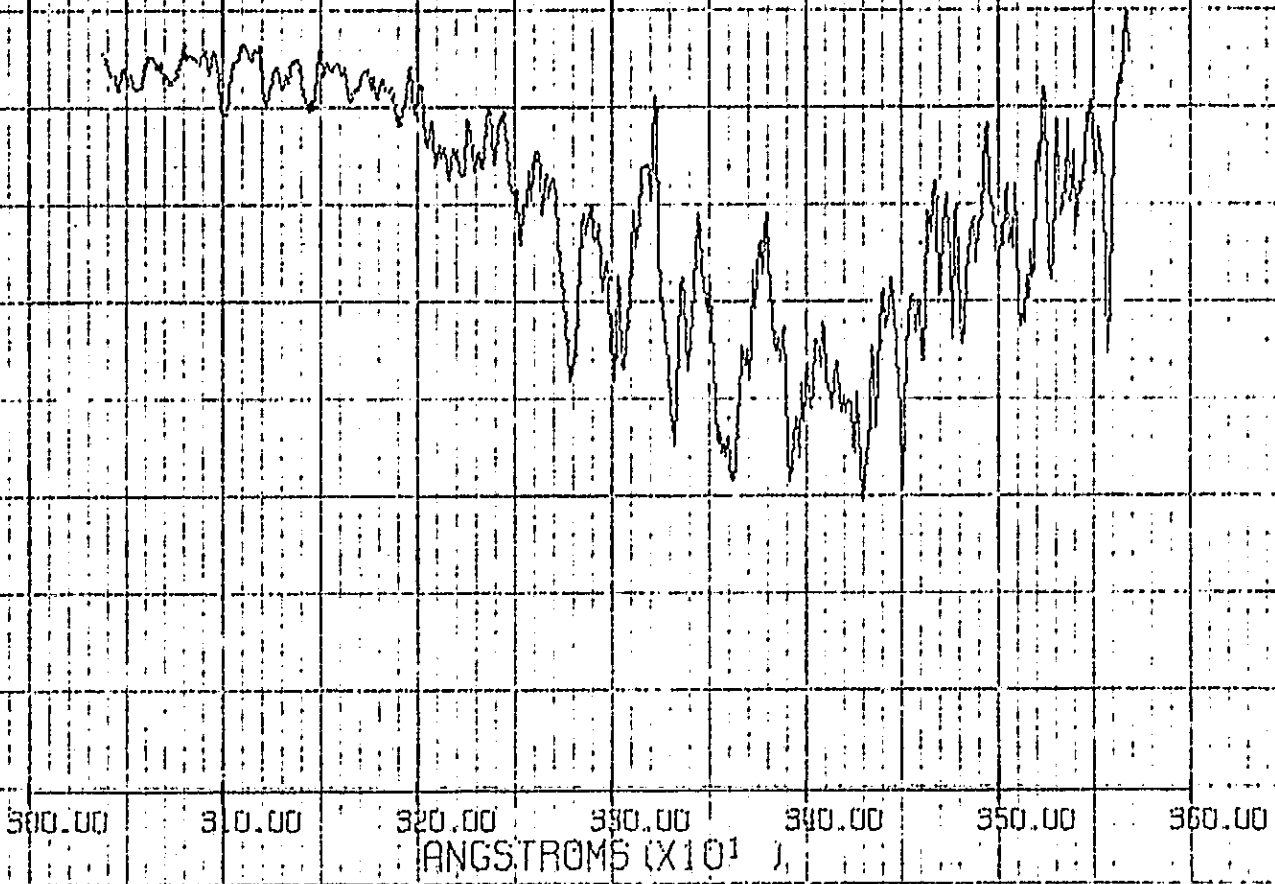


Figure 15

JPT / VNS + 800

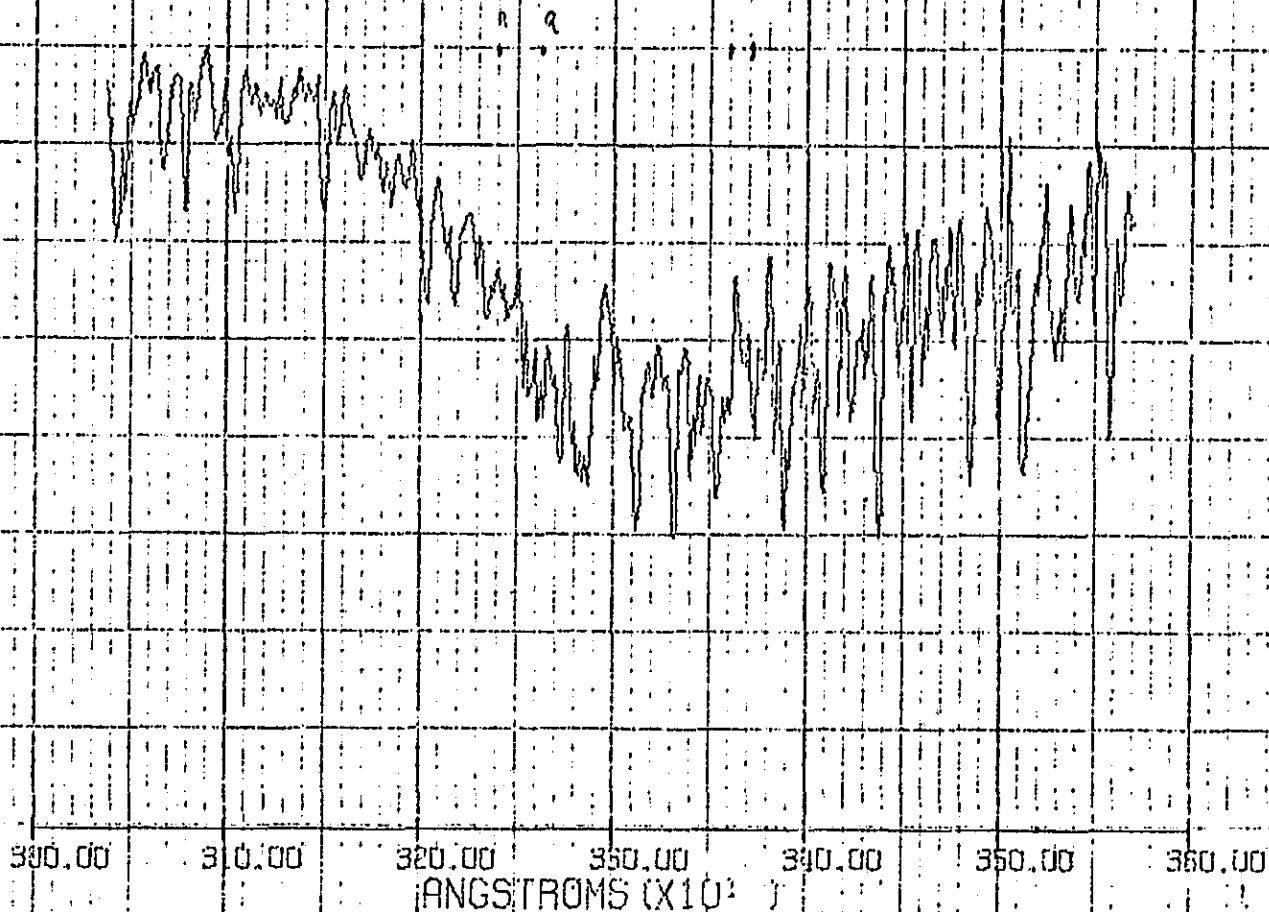


Figure 16

Figure 17 shows the path lengths through air and ozone as a function of zenith angle at airplane altitudes (~ 12 km).

A synthetic solar UV spectrum corresponding to 0.21 atm-cm of total vertical ozone content in the terrestrial atmosphere is shown in Figure 18. This synthetic spectral profile matches the measured solar UV spectrum (Figure 5). Hence the vertical ozone content in January 1973 was about 0.21 atm-cm around Moffett Field in California where the measurements were made.

DISCUSSION

The planetary spectra obtained by subtraction or by ratio techniques show a large amount of structure (Figures 11 and 19). We have concentrated on relatively prominent features as much of the finer structure may be spurious. Our approach in analyzing the difference spectra is to list molecules which we have reason to suspect may be present in the planetary atmospheres and which have absorption bands in the spectral range covered in our measurements. We then look for these bands in the difference and ratio spectra.

In the case of Venus, it has long been suspected that the very high surface temperatures are caused by eruptive activity resulting in very extensive lava flows. If this is the case, and recent Soviet results tend to support the eruption hypothesis, considerable amounts of sulfur and chlorine compounds should be present in the Venus atmosphere.

(There is also speculation that the clouds may be concentrated H_2SO_4 droplets.) The main absorption system of SO_2 , as listed in Pearse and

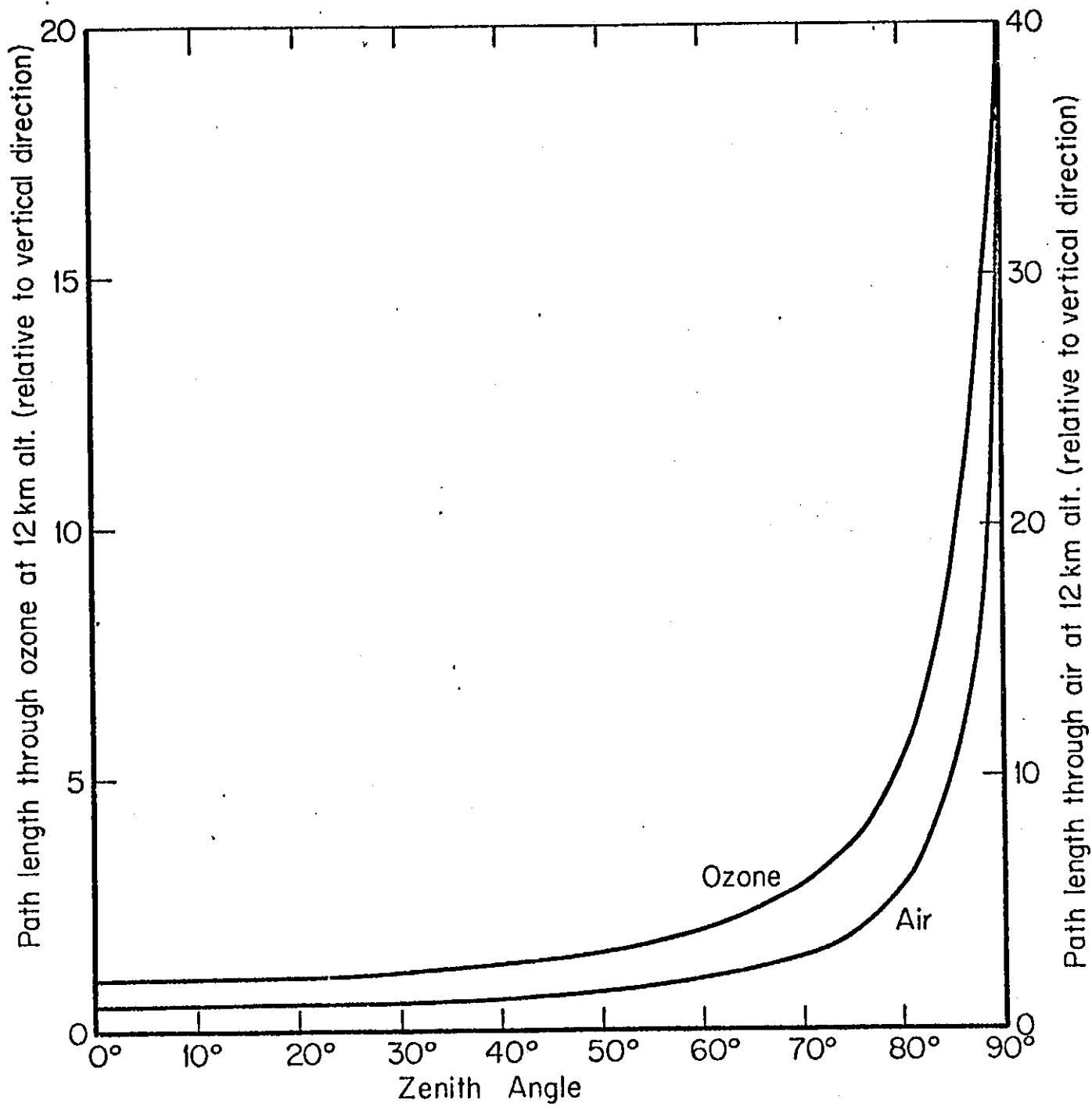


Figure 17

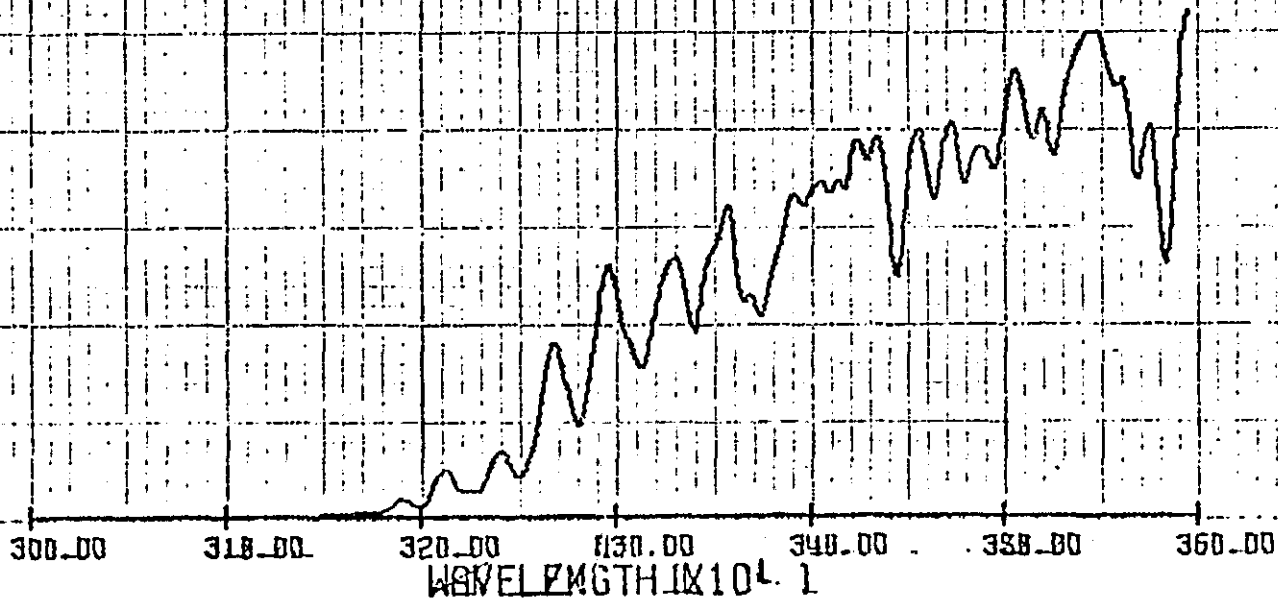


Figure 18

Gaydon (1950), has band maxima at 3190.9, 3181.1, 3173.0, 3167.0, 3159.0, 3151.8, 3131.3, 3129.5, 3108.4, 3087.7, 3065.9 and 3043.3 Å, within the wavelength range covered in our measurements. Some of these are too closely spaced to be resolved at 7 Å slit width. However, in the Venus minus sun spectrum (Figure 8) there are absorption features corresponding to most of these bands which is a strong indication that SO₂ is present in the Venus atmosphere.

SO₂ can be photo-dissociated to SO by a relatively low energy ($\lambda < 1950\text{Å}$) photon. Hence, if SO₂ is present one would naturally expect to see spectral signatures of SO in the Venus spectrum. For the $^3\Sigma \rightarrow ^3\Sigma$ ground state transitions, Pearse and Gaydon (1950) list the following SO bands in the wavelength region covered by our measurements: (1,11) at 3548.7Å, (0,10) at 3502.1Å, (1,10) at 3428.1Å, (0,9) at 3383.1Å, (1,9) at 3314.8Å, (0,8) at 3271.0Å, (2,9) at 3247.5Å, (0,7) at 3164Å, and (0,6) at 3064.1Å. Again, there are absorption features in the Venus minus sun spectrum (Figure 8) corresponding to most of these bands. Because of the large number of bands used in the identification, the probability seems quite high that the structure in the Venus spectrum represent spectral signatures of SO₂ and SO in the Venus atmosphere.

In addition to absorption bands of SO₂ and SO the Venus minus sun spectrum shows absorption features at wavelengths characteristic of ClO₂ at 3511.4, 3404.0, 3360.5, 3291.2, 3226.0, 3163.5, 3105.7 and 3050.9Å. If ClO₂ is indeed present on Venus it would imply quite a high rate of production because it is so easily photo-dissociated.

Features corresponding to other suspected molecules (e.g. CH₂O, NH, CS₂, S₂, etc) have also been found in the Venus minus sun spectrum, but

their identification rests on a lesser number of bands. More extensive measurements at higher resolutions are needed for more definitive decisions about their presence.

The Jupiter minus sun spectrum points to a relatively greater abundance of ClO_2 and less of SO_2 in the Jupiter atmosphere. There is also some evidence for the presence of CH_2O . Again much more extensive measurements are needed to provide conclusive evidence for the existence of these species in the atmosphere of Jupiter.

The general shapes of the Venus minus sun and Jupiter minus sun spectra are quite different. Venus has a considerably higher albedo in the region 3250-3450A than does Jupiter, i.e., Jupiter shows much more absorption in this wavelength interval than does Venus. More quantitative assessment of these and other features of both these planets must await more extensive measurements.

The solar UV measurements show a great potential for remote sensing total ozone concentration in the terrestrial atmosphere. Detailed spectroscopic measurements of solar UV combined with the synthetic spectral profile technique is superior to other ground based techniques for determining the total atmospheric ozone content.

ACKNOWLEDGMENTS

The author thanks NASA for providing financial assistance for this project. The success of this project is due mainly to the technical and moral support provided by Mr. L. C. Haughney, and other staff members of the Airborne Science Office as well as the crew of the CV 990.

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APPENDIX

BASIC PRINCIPLES INVOLVED IN AIRBORNE SCIENTIFIC PROGRAM OPERATION

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Presented at the

Payload Operation Crew Function Workshop

L. B. Johnson Space Center
Houston, Texas

April 16, 1974

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ABSTRACT

Through the speaker's extensive background in ground based and airborne experimental programs and many comments from members of the space science community, four main topics are recognized as important for successful airborne operations. These involve the concepts of the (1) Mission Manager - The Mission Manager concept in the Airborne Science Program begins at the onset of experiment and mission planning. Such an individual working closely with the experimenter and participating throughout the planning, preparation, and flight itself is very important. (2) Quality Control and Reliability - In the Airborne Science Program, it has been traditional that the experimenter is deeply involved in experiment hardware preparation and assumes all the responsibility for the experiment. (3) Individual Involvement - In the Airborne Program, the experimenter himself operates the equipment. The further we move

away from this concept, the more difficult and costly the experiment becomes to insure successful data return. Specifically, the hardware must tend toward automation, more testing, and the necessity for operator training--all of which increases cost and makes the whole operation less attractive. (4) Data Handling - Real time decisions require understandable data in useful units and formats. Any compromise degrades the success of the experiment. These topics are discussed specifically with regard to the Airborne Science Program but are basic concepts which have implications in the areas of management and program planning for the Shuttle and Spacelab.

INTRODUCTION

Don Mulholland has presented the overall view of the operation of the Airborne Science Office. I am here as a member of the Scientific Community to express our view point on the Airborne Science Program and its response to our needs. Hopefully, this will be of some interest to you in the development of the operational concepts for the Shuttle and Spacelab.

My main interests are in the atmospheric sciences, aeronomy and magnetospheric physics. Many of my colleagues and I recently gathered to discuss the scientific programs for future airborne, satellite and spacelab missions. I am sure that you are well aware of the difficulty in getting a group of scientists to agree on anything; however, in this case, I feel no hesitation in saying that most all scientists who have had direct experience with the Airborne Science Office have pretty much the same feelings that I do.

I have had extensive experience in a variety of remote land-based expeditions and have flown some 300 hours in the Ames Convair 990. I recently took part in the Ames ASSESS Program where several of us were confined on board the 990 for a five day mission which included four five-hour data gathering flights. It's from this experience and the comments from my colleagues that I have selected the four main points that I will discuss. I feel they represent basic concepts and hopefully will be of some assistance to this Workshop. These four topics concern:

- (1) Mission Manager
- (2) Quality Control and Reliability
- (3) Investigator Involvement
- (4) Data Handling

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TOPIC I.

The description of the role of the Mission Manager that Don discussed is a major role. However, I feel that I should more fully emphasize the interaction between the Mission Manager and the Principal Investigator. The association is one which covers all phases of the program. The Mission Manager is in contact with different PI's at a very early stage and it is through this involvement that the scientific community advances their interests in particular missions. This is, of course, not the only way, but having the Mission Manager in on the program development at an early stage helps. Once the experiments have been selected, direct communication between Mission Manager and the PI intensifies. This covers all of the specific details of the planned mission, tentative flight paths, allocation of space on the aircraft, installation dates, special windows, peculiar mounting problems, loan of NASA equipment, stress analysis, power requirements, special clothing requirements, and other details.

Upon installation of the equipment on the aircraft, the Mission Manager is the prime interface between the PI and the various aircraft crews. All requests for assistance, special tools, or on board facilities go through him.

The Mission Manager flies during the actual flights and continues in his role as go-between between PI and flight crew. Although discussions are held directly with the navigators and flight planners on a daily basis concerning flight schedules, the Mission Manager chairs the session. He also provides in-flight data on coordinates, power station control, communication and data recording. Major links between the aircraft and ground based or satellite programs with which the aircraft is coordinating observations, are guided by the Mission Manager.

Upon completion of the flight program the off loading of equipment, removal of special gear and distribution of data tape is handled through the Mission Manager. The distribution of flight records and logs for all flights comes from the Mission Manager. Thus, in summary, one might say that the Mission Manager is part of the program from conception through birth, growth and demise. One individual in such a position replaces much of the need for paperwork because the problems are presented and discussed verbally. The need for documentation on different systems is eliminated. The basic description of the on-board facilities, rules, and safety requirements in a simplified report are all that are needed. The details for each individual experiment are worked out between the investigators and the Mission Manager.

One of the major guidelines for operation on board the aircraft concerns the second point I will discuss on quality control and reliability of the equipment.

TOPIC 2.

In any program, there is always a problem with money. One always tries to get the most amount of useful information for the money that is available. The approach used in the aircraft program is to provide a basic facility with interface systems for power and data recording and to leave the development of the instrument and its reliability to the individual investigator. Concern of the Mission Manager is primarily on safety, internal compatibility between experiments, power and recording requirements and overall coordination. The details of reliability and instrument operation are vested in the investigators. This is obviously one area considered in the initial decisions as to which proposal and investigator is selected for the program. One should not select anyone who can not be trusted to consider the necessary items for a successful operation. In addition, no particular stigma is attached to the overall mission if one experiment has problems or fails completely. This is not a reflection on the mission concept, manager or crew but rests solely on the shoulders of the individual principal investigator and that is where the responsibility should be. This concept cuts costs because in the main existing operational equipment can be used, it cuts the paperwork completely and in general has made the programs much more productive for minimal amounts of money. Tied closely to this concept, however, is the involvement of the individual investigators themselves and how they are selected.

TOPIC 3.

In general, atmospheric earth and space scientists are accustomed to traveling all over the globe, sometimes spending many months away from

home on expeditions in the Antarctic, Arctic, or on the oceans. The operational concept of the Airborne Science Office fits into this pattern by allowing the scientist to take his own equipment on expeditions to obtain data to which he is otherwise denied when constrained to a ground based program. It is in this same category that we view the Shuttle and Spacelab programs.

This concept is obviously a completely new approach and challenge to the space program involving many complex problems. However, it is an economically sound concept and works successfully on the aircraft. We must realize that the more automated an instrument becomes the more costly it will become with greater jeopardy to the overall role of man in space. Many instruments can be operated and observations performed by routine procedures, however, many, especially in auroral observations or earth resource observations, require real time decisions and operational control by an individual. I'll summarize the need for individual scientists in four statements:

- (1) Real time decision making through interpretation of on-board observations.
- (2) On-board maintenance.
- (3) Guidance of instruments on the objects studied.
- (4) Economy of human control over completely automated systems.

However, emphasis must be placed on the selection criteria for the individual investigators. Their past training certainly is important. Obviously, any investigator or experiment not able to perform successfully on the aircraft will not perform on board the Spacelab. Perhaps an airborne experience should be considered as part of the required

training for spacelab investigators. However, in order to accomplish any of these tasks on board the aircraft or spacecraft, some attention needs to be paid to data handling and reduction.

TOPIC 4.

In this day of modern technology, there is no reason to continue to record data on strip charts, in voltage outputs or currents. On airborne expeditions, much of the data is processed on board the aircraft and converted into intensities in absolute units versus time and position. Interferometer data is Fourier analyzed on board into recognizable wavelength versus intensity values or spectrophotometer data is converted from digital counts to spectral data then compared to theoretical calculations during the mission to enable real time decisions on aircraft flight paths and inter-comparison with either on-board data as well as data obtained with ground or satellite coordinated observations.

This must be an integral part of the planning for the Spacelab not only for those instruments which are operated by investigators on board, but also those instruments which require only minimal in-flight attention.

In summary, let me repeat the four areas of primary concern:

(1) Mission Manager - The Mission Manager concept in the Airborne Science Program begins at the onset of experiment and mission planning. Such an individual working closely with the experimenter and participating throughout the planning, preparation, and flight itself is very important.

(2) Quality Control and Reliability - In the Airborne Science Program, it has been traditional that the experimenter is deeply involved in experiment hardware preparation and assumes all the responsibility for the experiment.

(3) Individual Involvement - In the Airborne Program, the experimenter himself operates the equipment. The further we move away from this concept, the more difficult and costly the experiment becomes to insure successful data return. Specifically, the hardware must tend toward automation, more testing, and the necessity for operator training--all of which increases cost and makes the whole operation less attractive.

(4) Data Handling - Real time decisions require understandable data in useful units and formats. Any compromise degrades the success of the experiment.

Lee Weaver is now going to continue this part of the program with more emphasis on the relationship of these and other ideas to the Shuttle and Spacelab management programs.