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AIRBORNE OBSERVATIONS OF THE COMET IKEYA-SEKI (1965f)

MAY 1966
DOUGLAS REPORT SM-52056

MISSILE & SPACE SYSTEMS DIVISION
DOUGLAS AIRCRAFT COMPANY, INC.
SANTA MONICA CALIFORNIA

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PREPARED UNDER CONTRACT NO. NASw-1352
BY THE DOUGLAS AIRCRAFT COMPANY, INC.
MISSILE AND SPACE SYSTEMS DIVISION
SANTA MONICA, CALIFORNIA
FOR THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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PREFACE

This document is submitted by the Douglas Aircraft Company, Inc., to the National Aeronautics and Space Administration's Headquarters, Washington, D. C. It presents the results of the airborne observations of the comet Ikeya-Seki, and an analysis of photographic procedures adapted for use in a high-flying aircraft. This work was performed under Contract No. NASw-1352.

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ABSTRACT

On the NASA Ames Research Center 1965 Airborne Comet Expedition to Hawaii, photographs of the comet Ikeya-Seki (1965f) were obtained with a telescope-stabilization system. Selected photographs of the comet are presented. Between 17 October and 25 October 1965 (perihelion was on October 21.17767 Ephemeris Time, 1965), there were eight observational flights made aboard the NASA Ames jet aircraft. The comet was sighted on six flights and photographed on five. To evaluate the airborne stabilization system, photographs of the moon and Venus also were obtained. Conclusions are presented regarding both the comet observations in particular and airborne astronomical observations in general.

ACKNOWLEDGMENT

Appreciation is extended for the cooperation given the Douglas team by the NASA Ames Research Center, particularly to Dr. M. Bader, who directed the airborne expedition, and R. M. Cameron, NASA's principal investigator on the Douglas/NASA team. Douglas personnel participating in the flight were E. V. Petersen (principal investigator), Dr. P. C. Steffey (astronomer), and J. D. Clarke (electronics engineer). On the last two flights (25 and 26 October), another stabilized mirror system became available for use when the University of Arizona team left the expedition. J. D. Clarke (Douglas) and R. Innes (University of California) collaborated to photograph the comet with this equipment also. Through the courtesy of Messrs. Clarke and Innes, one of their photographs (Figure 6-2) appears in this report; however, their findings will not be reported.

J. D. Gehris (Douglas mechanical design engineer) was responsible for designing and fabricating the necessary equipment mounting fixtures for the aircraft and also supervised two Douglas technicians, D. McLaughtin and F. White, who installed the equipment aboard the aircraft at Moffet Field, California.

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FIGURES

Section 1

INTRODUCTION

In the early morning of 18 September 1965, two Japanese amateur astronomers sighted a new comet. Because the discovery by the two astronomers was simultaneous, the comet was labeled with their surnames, that is, "Ikeya-Seki."

It was soon learned that Ikeya-Seki was on a track similar to that of the sungrazing comet 1882 II. The great comet of 1882 passed within 0.00775 astronomical units (AU) from the sun on 17 September 1882. Near the time of perihelion, the comet's nucleus with a 20 arc-min. tail was bright enough to be seen with the naked eye during the day. The comet continued to be visible to the naked eye until mid-February 1883, several months after perihelion. Thirteen days after perihelion (30 September 1882), the nucleus was observed to separate into two nuclei. By October, multiple structures of the nucleus (four or five centers) elongated roughly along the tail were reported by European observers (Reference 1).

Astronomers predicted that the comet Ikeya-Seki would pass close to the sun, and that the comet's general behavior would be similar to the comet of 1882. The perihelion of Ikeya-Seki was calculated to be 0.00777559 AU, or a distance of 0.00312299 AU (290,000 mi) from the sun's surface on October 21.17767 Ephemeris Time (ET), 1965. Because the comet would pass so near the sun, and because its path was similar to that of the 1882 comet, it was felt that Ikeya-Seki would be a spectacular observation.

Because the trajectory of Ikeya-Seki would make ground-based observations in the middle northern latitudes difficult, an airborne expedition from the NASA Ames Research Center, Moffett Field, California, was planned to observe the comet from the lower northern latitudes. A Convair CV-990 jet aircraft was used for the expedition.

The Missile and Space Systems Division (MSSD) of the Douglas Aircraft Company, Inc., was invited to participate in the expedition because of the Company's background in airborne astronomical observations and because of the availability to MSSD of a proven stabilized telescope system for use in a jet aircraft.

The first objective of the expedition was to obtain a photographic life history of the general appearance of the comet head and near tail before and after perihelion passage. Of general interest were changes in the general morphology of the comet and possible disruption of the nucleus.

The second objective of the expedition was to obtain information on the feasibility of airborne observations of Venus (Reference 2). The conditions necessary to observe the comet near the sun approximate those conditions which will be encountered in the proposed observations of Venus near inferior conjunction.

This report contains a description of the instrumentation and flight observation procedures, a flight diary, data analysis, and conclusions. The conclusions are based upon simple analyses of selected photographs and observations of flight personnel, and will pertain both to observation of the comet in particular and to airborne astronomy in general.

Section 2

AIRBORNE STABILIZED TELESCOPE SYSTEM

The Ikeya-Seki comet was photographed with a Questar telescope and a two-axis gyroscopically controlled heliostat system mounted aboard the NASA-Ames CV-990 jet aircraft.

2.1 HELIOSTAT SYSTEM

The heliostat system was designed by Douglas and used on the Douglas-Mt. Wilson spectrograph experiment in conjunction with the Airborne Solar Eclipse Expedition (Project ASEE) in 1965, which was sponsored by NASA. The heliostat is a two-axis stabilized platform on which a mirror is mounted. The heliostat system reflects the image of a celestial object into a telescope, despite the motion of the aircraft.

Performance data of the heliostat system were collected on the 1965 ASEE (Reference 3). A study of image stability was made with the aid of motion picture film taken during the eclipse flight. A 16-mm motion picture camera (four frames per second) was mounted so that it monitored, via the heliostat system, the position of Jupiter (visible during totality) relative to a pair of orthogonal reference lines. The heliostat corrects for linear motions on the image plane but not for the rotary motion around the line of sight. Thus, the only indication of heliostat accuracy that can be taken from the film is a measure of the radial position of Jupiter with respect to time. The average radial deviation of four sample periods of 100-sec each (100 sec was the exposure time for one spectrogram on the eclipse flight) was 0.35 arc-min. rms. For the comet expedition, the exposure times were anticipated to be about 1 to 3 sec or less. To obtain an idea of the probable heliostat image stability, the four 100-sec sample periods were analyzed to determine the maximum peak-to-peak radial excursion for time intervals of 2.5, 5.0, 10.0, and 20.0 sec. In photography, any image excursion will degrade quality, and it was for this reason that the stability was analyzed for peak-to-peak excursions. The results of the analysis are shown in Figure 2-1. The four curves in the figure represent different time exposures, thus illustrating the degree of stabilization for different exposure settings.

2.2 QUESTAR TELESCOPE

The Questar telescope was used because of its versatility and availability. The telescope has a 3.5-in. clear aperture. A Nikon F, 35-mm camera was connected to the telescope. As a result of changing an extension tube between the camera and the telescope, the telescope system could be operated at

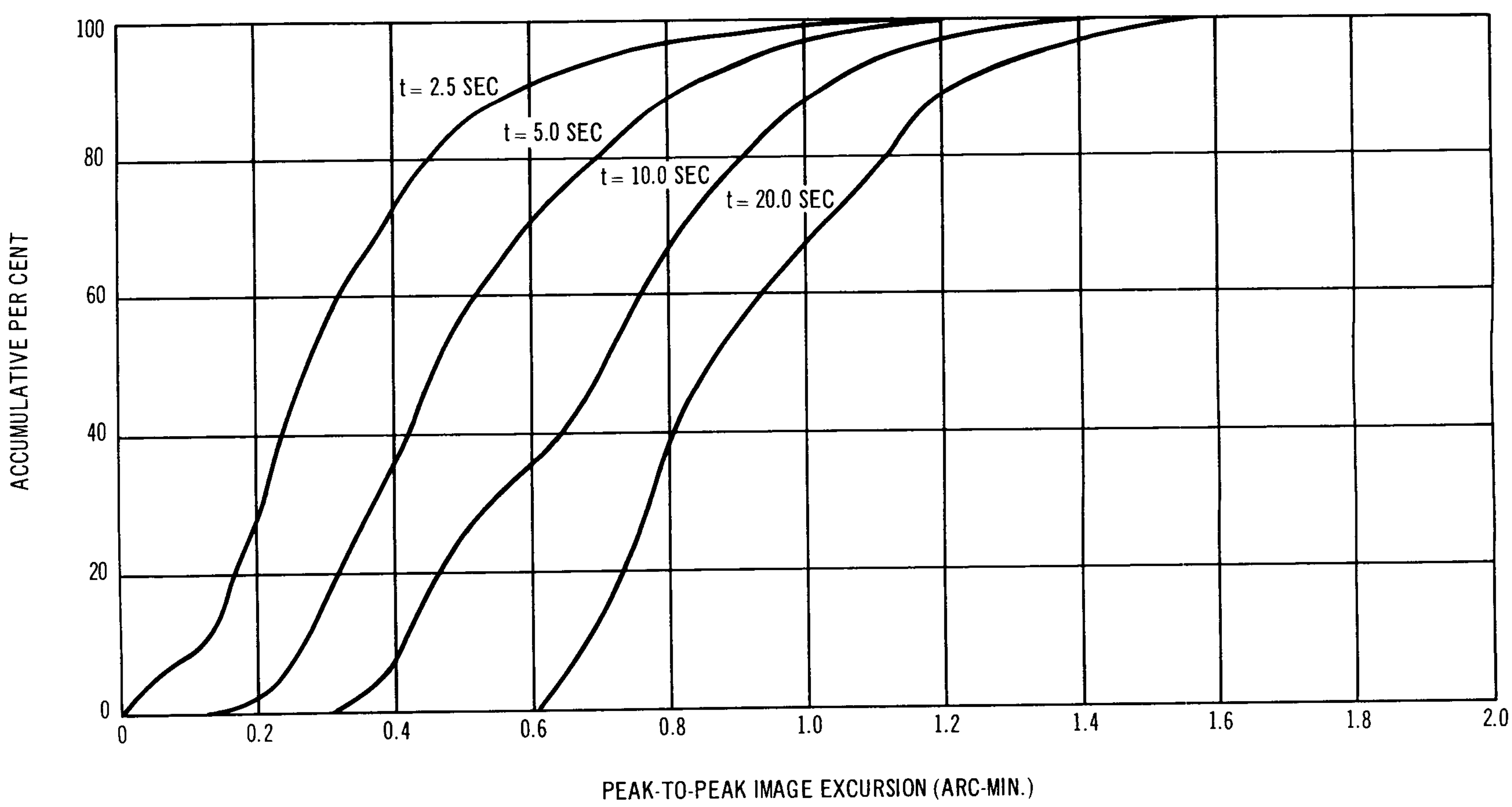


Figure 2-1. Accumulative Percent of Peak-to-Peak Image Excursion, Based on 400 sec Total Sample Period

either f/16 or f/18. Visual guidance on the comet was through the 40-80x eyepiece. The optical characteristics of the Questar telescope are as follows:

Clear aperture	3.505 in.	3.505 in.
f/number	f/16	f/18
Focal length	56 in.	64 in.
Plate scale	145.05 arc-sec/mm	126.88 arc-sec/mm
Field of view at 35 mm film plane (35 mm x 24 mm)	84.6 arc-min. x 58.0 arc-min.	74.0 arc-min. x 50.75 arc-min.
40-80x eyepiece in search mode	Power 4x	Field of view 12°
80-160x eyepiece in search mode	Power 8x	Field of view 8°

2.3 INSTRUMENTATION MOUNTING

The equipment was installed on the NASA-Ames CV-990 at station 1, the fourth window from the forward passenger door. Both the heliostat and telescope base were attached rigidly to an aluminum platform, 48 in. long x 24 in. wide x 21.5 in. high, which was fastened to the aircraft floor. The heliostat mirror view was through one of the passenger windows, which had been replaced with a plate glass optical window, 10 in. wide x 14 in. high x 1 in. thick, set at 14° elevation (Figure 2-2).

Once the optical alignment was made between the heliostat mirror and telescope, the telescope system was prevented from moving in its azimuth and elevation axes by a rod installed into the camera tripod mount and secured to the platform. Thus, the telescope was held fixed at two points along its optical axis.

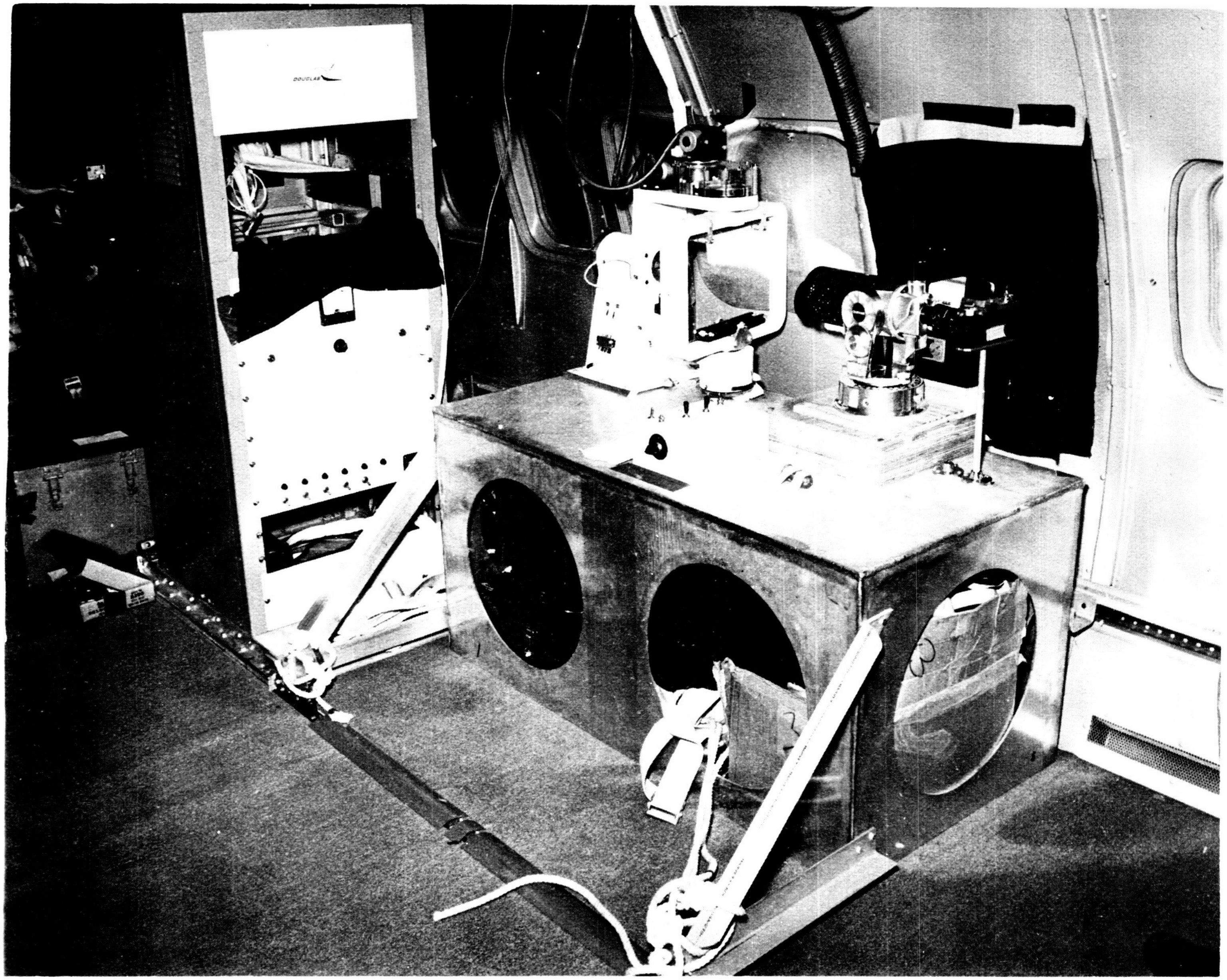


Figure 2-2. Airborne Installation of Telescope System Aboard NASA-Ames Convair 990

Section 3
FLIGHT OBSERVATION PROCEDURE

The operational procedure of the heliostat-telescope system involved the coordination of three people: one to operate the telescope and guide on the comet, a second to operate the camera, and a third to log the events.

Once the aircraft was on course and the comet was located, the telescope operator activated the heliostat system and located the comet in the 40-80x Questar eyepiece by slewing the heliostat mirror axes, through manipulation of the azimuth and elevation axes switches on a control unit. The operator then focused the image in the camera and positioned it on the camera view glass. The camera operator loaded the camera, advanced the film, took the exposures, and relayed the film type, exposure setting, and time of exposure to the third person for entry into the log.

Section 4

DIARY OF COMET OBSERVATIONS AND EVENTS

The NASA-Ames expedition left Moffett Field, California, for Hawaii on 16 October 1965 and returned to Moffett Field on 28 October 1965. Eight comet flight observations were made from Hickam AFB, Hawaii, during the period 17 October through 26 October aboard the NASA-Ames CV-990 jet aircraft. The comet was sighted on six flights and photographed on five flights. The following subsections contain a summary of the expedition.

4.1 FRIDAY, 15 OCTOBER 1965

Equipment was installed in the aircraft at Moffett Field.

4.2 SATURDAY, 16 OCTOBER 1965

The expedition left Moffett Field for Hickam AFB, where the optical alignment between the heliostat and telescope was checked.

4.3 SUNDAY, 17 OCTOBER 1965 (MORNING OBSERVATIONAL FLIGHT)

At 14:04 UT (4:04 a.m. Hawaiian Standard Time, HST), the first comet observational flight took place. Although few people sighted the comet, the NASA-Douglas team located it at about 15:55 UT through 10 x 50 and 7 x 50 binoculars. The comet was difficult to observe because of its low intensity and short tail. Through the Questar 40x eyepiece, the comet's head appeared kidney-bean shaped, with the convex side as the leading edge. The elevation angle of the comet at sunrise was approximately 10.9°. The comet was photographed on Kodak Tri-x film with the Questar set at f/16. The NASA-Douglas team were the only personnel onboard the flight to obtain photographs of the comet.

4.4 MONDAY, 18 OCTOBER 1965

No observational flight was made. Minor modifications to the instrumentation were accomplished.

4.5 TUESDAY, 19 OCTOBER 1965 (MORNING OBSERVATIONAL FLIGHT)

Takeoff was at 13:58 UT (3:58 a.m. HST). The comet, silhouetted against the morning twilight sky, was sighted with 10 x 50 binoculars, but it could not be located with the telescope.

The problem of location was attributed to the deterioration of contrast of the comet against the twilight sky. Because the twilight sky on this flight was sufficiently intense to wash out the comet's tail, only the head was visible. In addition, the twilight sky scattered off the optical window and heliostatic mirror, which also caused reduction in the contrast. The net result was that the faint image of the comet could not be located in the Questar 4x, 12° field-of-view search mode or with the 40x eyepiece 55-min. field of view. The elevation angle of the comet at sunrise was approximately 4.7°. The University of Arizona observation team discovered that a narrow-band (10 Å wide) sodium D interference filter enhanced the image contrast. This image enhancement with the filter permitted the University of Arizona observers to follow the comet easily, even after sunrise. Apparently, the comet was emitting in sodium D.

4.6 WEDNESDAY, 20 OCTOBER 1965 (EVENING OBSERVATIONAL FLIGHT)

In the morning (10:00 to 11:30 a.m. HST), the comet could be seen from the ground with binoculars, Questar telescope, and the naked eye aided by a sodium D filter. At 2:00 p.m. (0^h UT, 21 October 1965), the comet could be seen from the ground with the naked eye. Since the comet had been observed that morning, an obvious curvature had developed in the tail. The tail's angular extent at 2:00 p.m. was less than the sun's diameter, approximately 20 arc-min.

Takeoff was at 3:30 p.m. (01:30 UT, 21 October 1965), and the search for the comet started at 5:12 p.m. (03:12 UT, 21 October 1965).

None of the observers sighted the comet. At the start of the observation, the comet was approximately 11 arc-min. from the sun's surface, and the proximity of the sun to the optical axis of the telescope necessitated great care in guiding. Although the sun was low on the horizon, the bright skylight and scattered sunlight off the optical window was enough to wash out the comet's image, even when searching with binoculars shaded from the sun. The comet could not be seen, even with a sodium D interference filter in front of the telescope aperture. Photographs were taken of the area where the comet should have been relative to the sun; none of the photographs showed images.

The sun set at 04:45 UT, 21 October 1965 (18:45 HST, 20 October 1965). After sunset, the aircraft was flown west for 34 min. (approximately 4° longitude at a latitude of 21.5°N) and turned at 5:12 UT onto a northwest course to search for the comet's tail. The tail was not sighted. Apparently, the angular extent of the tail had not developed as anticipated.

Attention was then directed to photography of Venus. Kodak Plus-x, high-contrast copy, and Panatomic-x film were used. When observed through the 40x eyepiece, the image of Venus vibrated, giving the appearance of astronomical image motion. The out-of-focus image of Venus and a star (doughnut appearance) near 40° elevation were examined for intensity variation with the 40-80x eyepiece, but they did not reveal noticeable intensity variation. To reduce the noted image vibration, vibration damping of the platform would have to be incorporated for future airborne astronomical image photographic experiments.

4.7 THURSDAY, 21 OCTOBER 1965 (MORNING OBSERVATIONAL FLIGHT)

Takeoff was at 13:20 UT (3:20 HST). The search for the comet's tail began 94 min. before the comet was predicted to rise. There was a 12-min. time separation between comet rise and sunrise. At sunrise, the elevation angle of the comet was calculated to be 2.6°. None of the experimenters sighted either the tail or head of the comet. Again, the angular extent or the intensity of the tail did not develop as expected. As an alternative task, the moon was photographed with Kodak Plus-x and high-contrast copy film. The moon was past last quarter, and the lunar earthshine was sufficiently intense to see easily the outlines of the maria in the telescope.

4.8 FRIDAY, 22 OCTOBER 1965

No flight to observe the comet was made. A meeting between the NASA expedition and Project PRESS personnel was held at Hickam AFB to discuss and exchange ideas on the problems of daytime astronomical photography, particularly when the object is near the sun.

4.9 SATURDAY, 23 OCTOBER 1965 (MORNING OBSERVATIONAL FLIGHT)

Takeoff time was 14:24 UT (4:24 a.m. HST). The comet's tail was first sighted with 7 x 50 binoculars (10° field of view) several minutes before the head rose at 15:31 UT. Through the binoculars, the comet appeared to subtend an arc of 8° to 10° at 15:31 UT (comet rise). At 15:36 UT, one observer reported that the intensity of the twilight sky had increased enough so that, with a pair of 10 x 50 binoculars (5.5° field of view), the tail length was reduced to 4°; at 15:56 UT the tail was only 1.5°. The comet head was located in the Questar by first locating the tail and then guiding down the tail to the head.

The contrast of the comet was increased by inserting a sodium D filter over the telescope eyepiece. Photography began at 15:36 UT, with Plus-x, Tri-x, extended range, and Panatomic-x films, and with the telescope set at f/16. Sunrise (16:08 UT) was 37 min. after comet rise, and, at sunrise, the comet elevation angle was 9.4°. At 16:05 UT (3 min. before sunrise), it was difficult to see the comet through binoculars, although it was easily seen through the telescope.

The comet head was followed for 42 min. after sunrise with the Questar, by using the 40x eyepiece covered with the sodium D filter. When the filter was removed, the comet head was undetectable. The head was tracked to an elevation angle of approximately 16°, at which time the aircraft returned to Hickam AFB.

At one time after sunrise, a cloud bank which shaded the optics from the direct sunlight was passed. When this happened, more of the extended tail was visible than when the sun was shining directly on the optical window. The separation angle between the comet head and the sun was approximately 11.7°.

4.10 SUNDAY, 24 OCTOBER 1965 (MORNING OBSERVATIONAL FLIGHT)

Takeoff was at 13:57 UT (3:57 a.m. HST). On this flight, the comet's tail was sighted at 15:05 UT, which was 16 min. before the head rose and was sighted in the telescope (15:21 UT). By using binoculars, it could be estimated that the comet subtended an arc between 8° to 9°. Since the comet rose 46 min. before sunrise, the sky was dark enough that the comet could be seen with the naked eye. The tail curvature was easily noticed. Through the telescope, the comet head had the appearance of being kidney-bean shaped, with the convex side as the leading edge. Photographs of the head were made on Plus-x and extended range film with the telescope set at f/16. At sunrise, the comet was 11.7° above the horizon.

4.11 MONDAY, 25 OCTOBER 1965 (MORNING OBSERVATIONAL FLIGHT)

Takeoff was at 13:27 UT (3:27 a.m. HST). Comet rise was calculated to be at 15:11 UT; however, because of clouds on the horizon, the head was not sighted until 15:15 UT. The head was sighted 48 min. before sunrise (16:03 UT). At 14:40 UT, the comet tail was sighted, which was 35 min. before the head was sighted on the horizon in the telescope. At 14:46 UT, the tail extended 5° above the horizon; the tail width at the horizon was 0.8°. The tail was curved to the north. At 15:00 UT, the tail width at the horizon was 0.4°. At 15:04 UT, the tail was estimated to be two or three times brighter than the zodiacal light. A few minutes after the commet head has risen (15:18 UT), the comet was estimated to subtend an arc of approximately 9°. The navigator, by using a sextant, measured the comet to be 7°10' at 15:24 UT. Photographs of the comet head were taken with Plus-x, extended range, and high-speed Ektachrome, with the telescope set at f/18. At sunrise, the comet was 13.8° above the horizon.

4.12 TUESDAY, 26 OCTOBER 1965 (MORNING OBSERVATIONAL FLIGHT)

Takeoff was at 13:05 UT (3:05 HST). The comet head was expected to rise at 15:09 UT, and the sun at 16:14 UT. At 14:27 UT, the comet tail was sighted through binoculars; this was 47 min. before the head rose. At

15:05 UT, the head was sighted low on the horizon (negative elevation angle) through the telescope. The comet head did not appear any different than on the previous days. Multiple structure of the head was sought, but not detected. At 15:12 UT, the navigator measured the vertical projection of the comet at 11°11' with his sextant. The comet was photographed with Plus-x, Tri-x, extended range, and high-speed Ektachrome film, with the Questar set at f/18. At sunrise, the comet elevation angle was approximately 17°.

4.13 WEDNESDAY, 27 OCTOBER 1965

Preparation was made for the flight back to Moffett Field, California.

4.14 THURSDAY, 28 OCTOBER 1965

The flight was made from Hickam AFB, Hawaii, to Moffett Field, California.

Section 5

NAVIGATION MAPS

Figure 5-1 contains maps of the flight paths of the NASA 1965 Airborne Comet Expedition for the following dates: 17, 19, 21 (two flights), 23, 24, 25, and 26 October 1965 (UT). The maps were supplied by the NASA Ames Research Center.

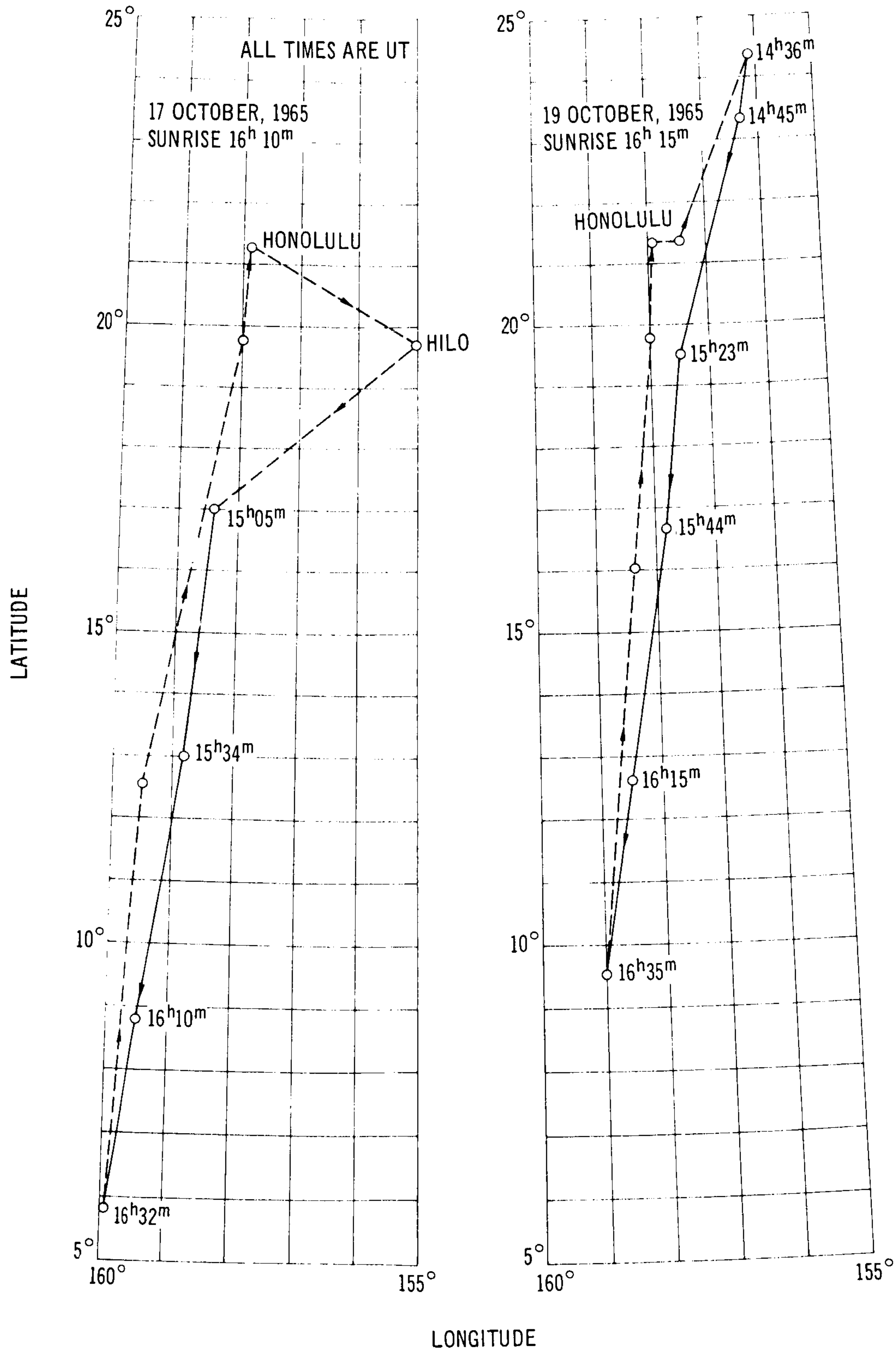


Figure 5-1. Flight Paths (Page 1 of 5)

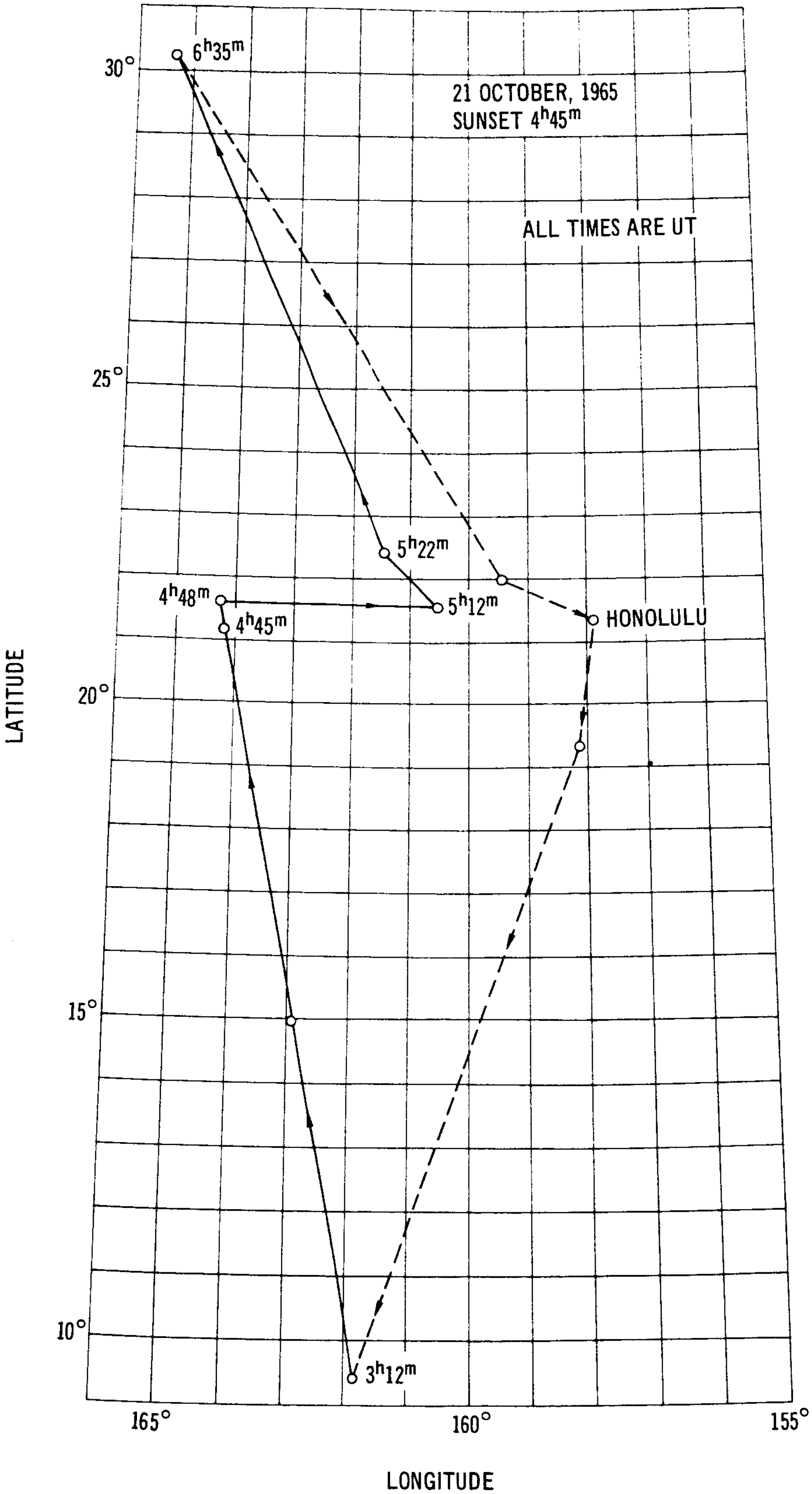


Figure 5-1. Flight Paths (Page 2 of 5)

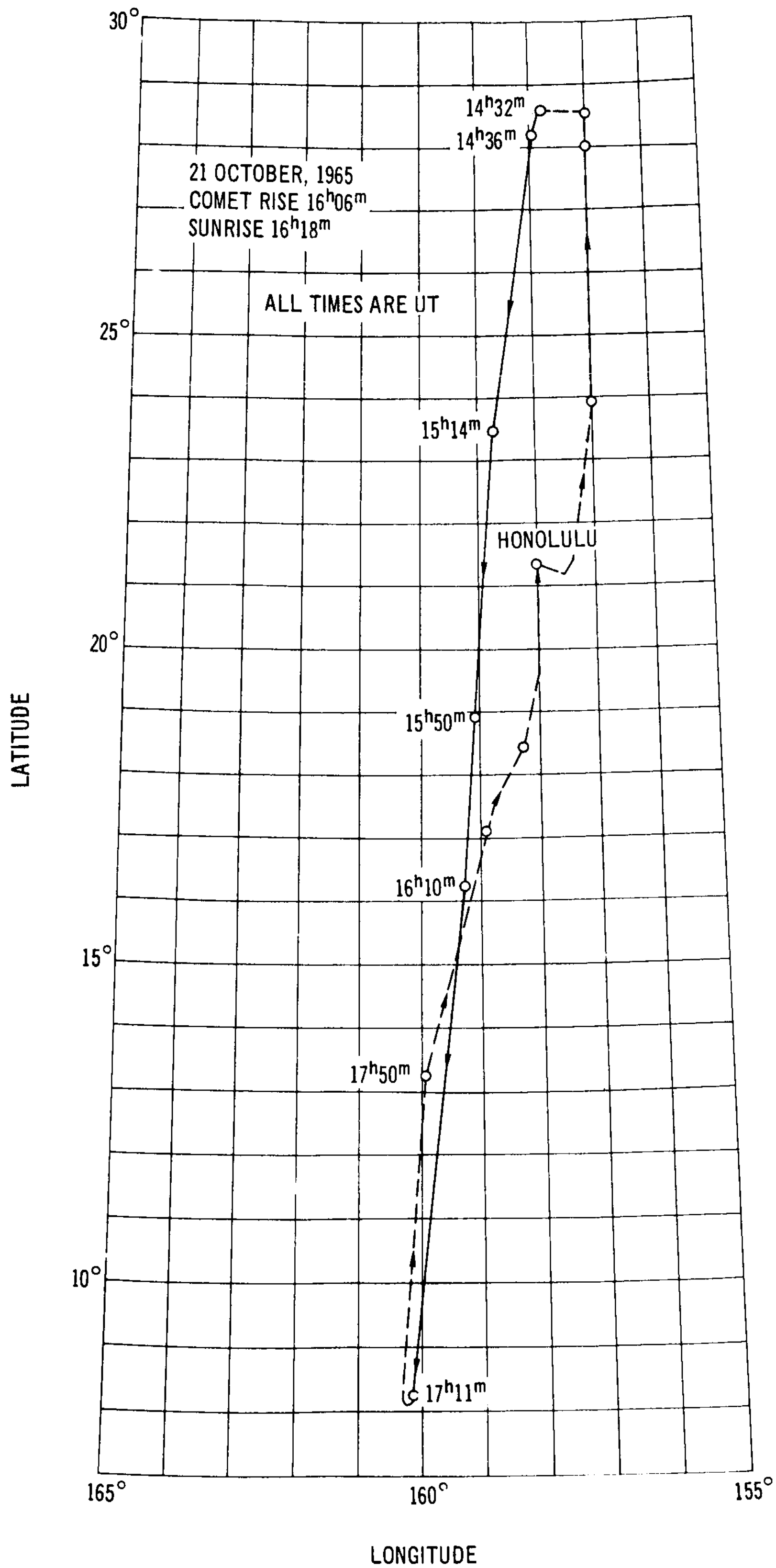


Figure 5-1. Flight Paths (Page 3 of 5)

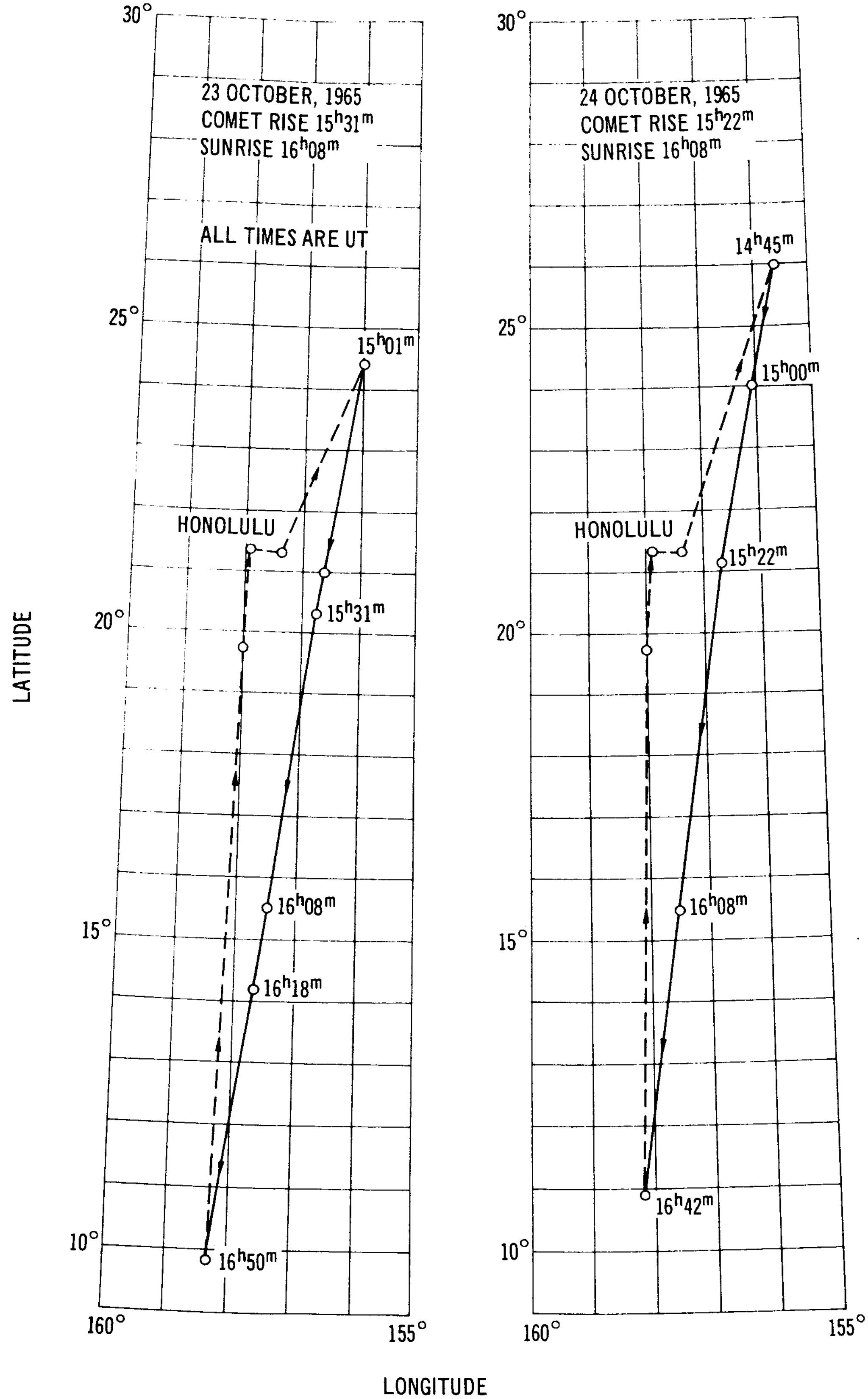


Figure 5-1. Flight Paths (Page 4 of 5)

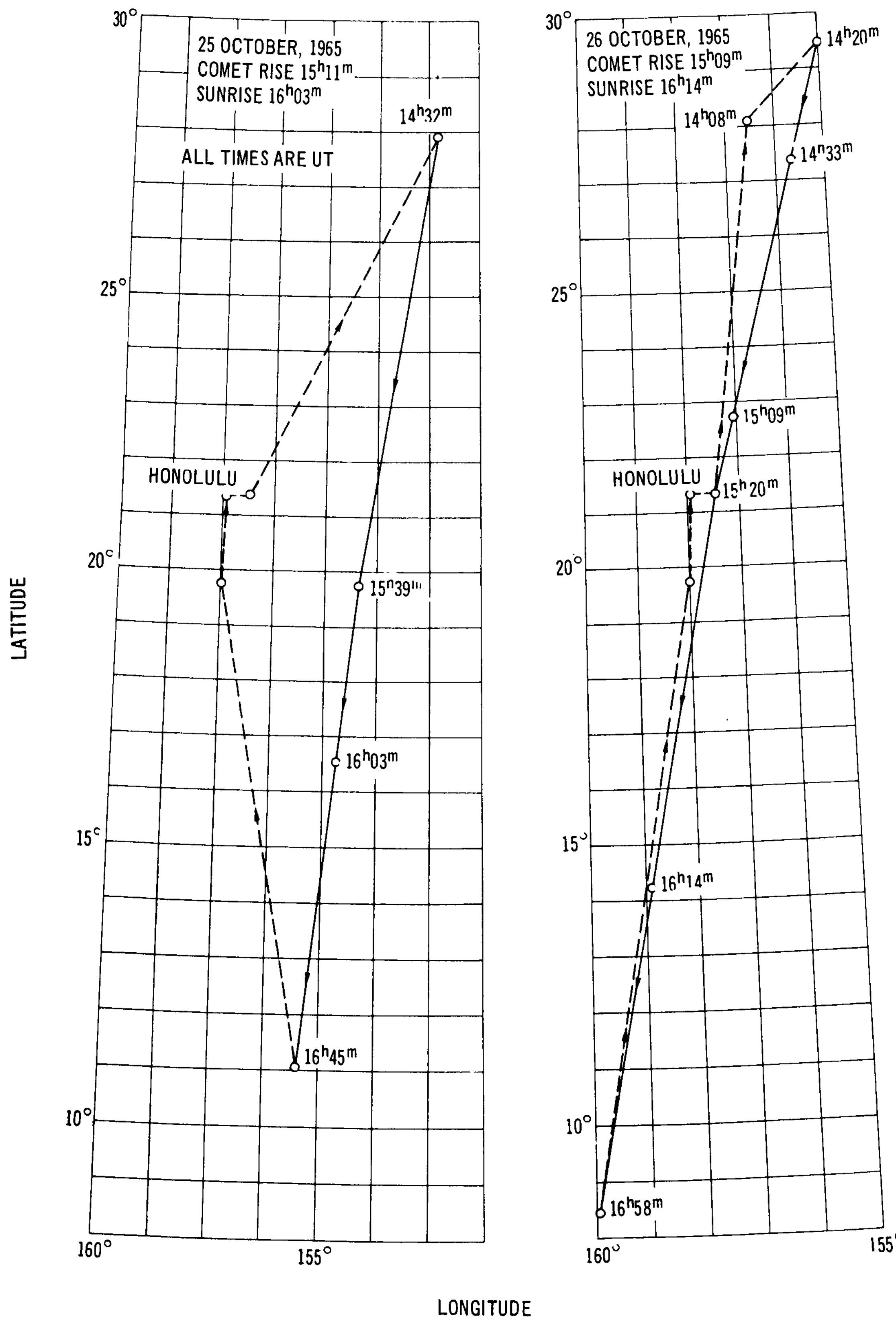


Figure 5-1. Flight Paths (Page 5 of 5)

Section 6
DISCUSSION

This section discusses specific objectives which were outlined in the proposal.

6.1 GENERAL MORPHOLOGICAL CHANGES OF COMET

The most noticeable change in the comet during the expedition was the increased angular extent of the tail after perihelion. On 17 October 1965 (before perihelion), the entire comet could fit within the telescope's photographic field of view and measured approximately 4.8 to 5.0 arc-min. (Figures 6-1A and 6-1B) from the negatives. Successful observations of the comet after perihelion (23 October through 26 October 1965) showed a tail length estimated to be between 8 and 11 arc-deg (Figure 6-2). A Douglas/University of California (Berkeley) team used a similar gyrostabilization system to obtain the photograph of the comet in Figure 6-2.

A band structure in the comet's tail was evident in some negatives acquired after perihelion. The band structure is shown in Figures 6-3A, 6-3B, 6-4A, and 6-4B. Figures 6-3B and 6-4B are prints made from the NASA-Ames contact printing Fluor-O-Dodge instrument that was used to greatly increase print contrast. The comet's elongated head in Figure 6-3A was caused by image motion; however, this picture was selected because it best demonstrates the band structure in the near tail of the comet.

A close examination of the negatives was made to detect possible separation of the nucleus into separate bodies. No separation of the nucleus was evident in data compiled through 26 October 1965.

6.2 ASTRONOMICAL SEEING

Some quantitative estimate on astronomical seeing (discussed in Section 4.6) was made when either Venus or a star was viewed through the telescope. The out-of-focus image of Venus or the star (both were near 40° elevation) was relatively free from intensity variations when viewed through the 40-80x magnification eyepiece. Photographs of an out-of-focus image of Venus were made at altitude and are shown in Figure 6-5A and 6-5B, which were taken at 1 and at 1/2 sec exposure, respectively. The intensity distribution of the doughnut appears fairly uniform. It was concluded by the observers at the telescope that the image motion and scintillation were noticeably reduced at altitude. However, it was noticed also that the image of Venus appeared to vibrate in the 40x magnification eyepiece. This was attributed to aircraft vibration being transmitted to the telescope and its platform. This vibration made focussing on Venus difficult, as evidenced by examination of the negatives, which

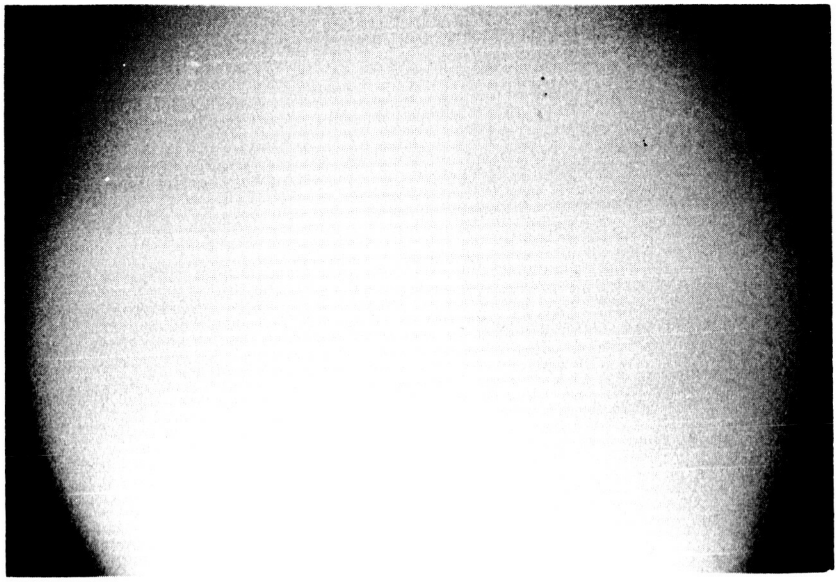


Figure 6-1A. (Enlargement 5X)

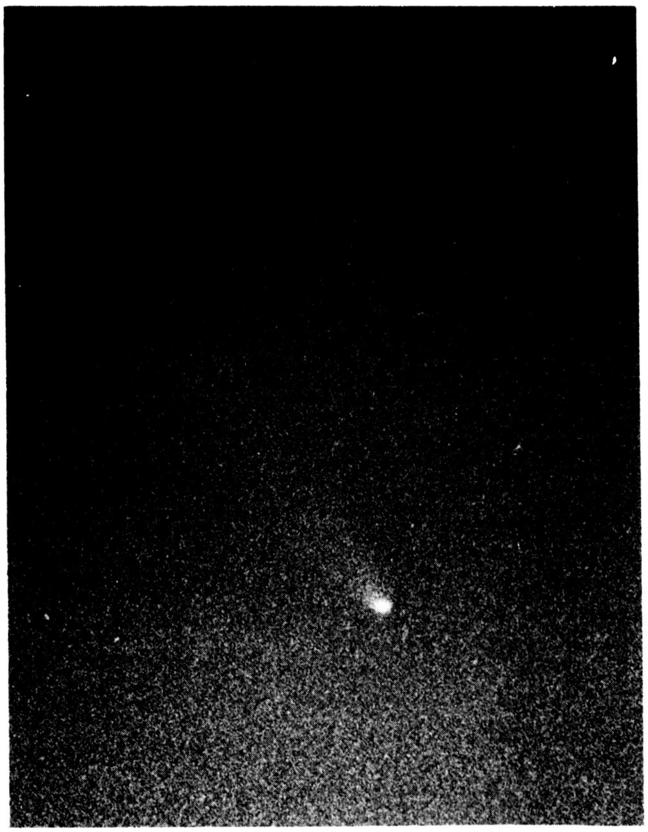


Figure 6-1B. (Enlargement 7½X)

NOTE:
1. FILM: KODAK TRI-X
2. EXPOSURE TIME: 4 SEC AT f/16

Figure 6-1. Photographs (Different Enlargements) of Comet Ikeya-Seki Taken on 17 October 1965 at 15:59 UT

NOTE:
1. EXPOSURE TIME: 3 SEC
2. FILM: TRI-X; 105 mm, f/2.5

Figure 6-2. Comet Ikeya-Seki Photographed from NASA-Ames Convair 990 Jet Aircraft on 26 October 1965 at 15:29:30 UT

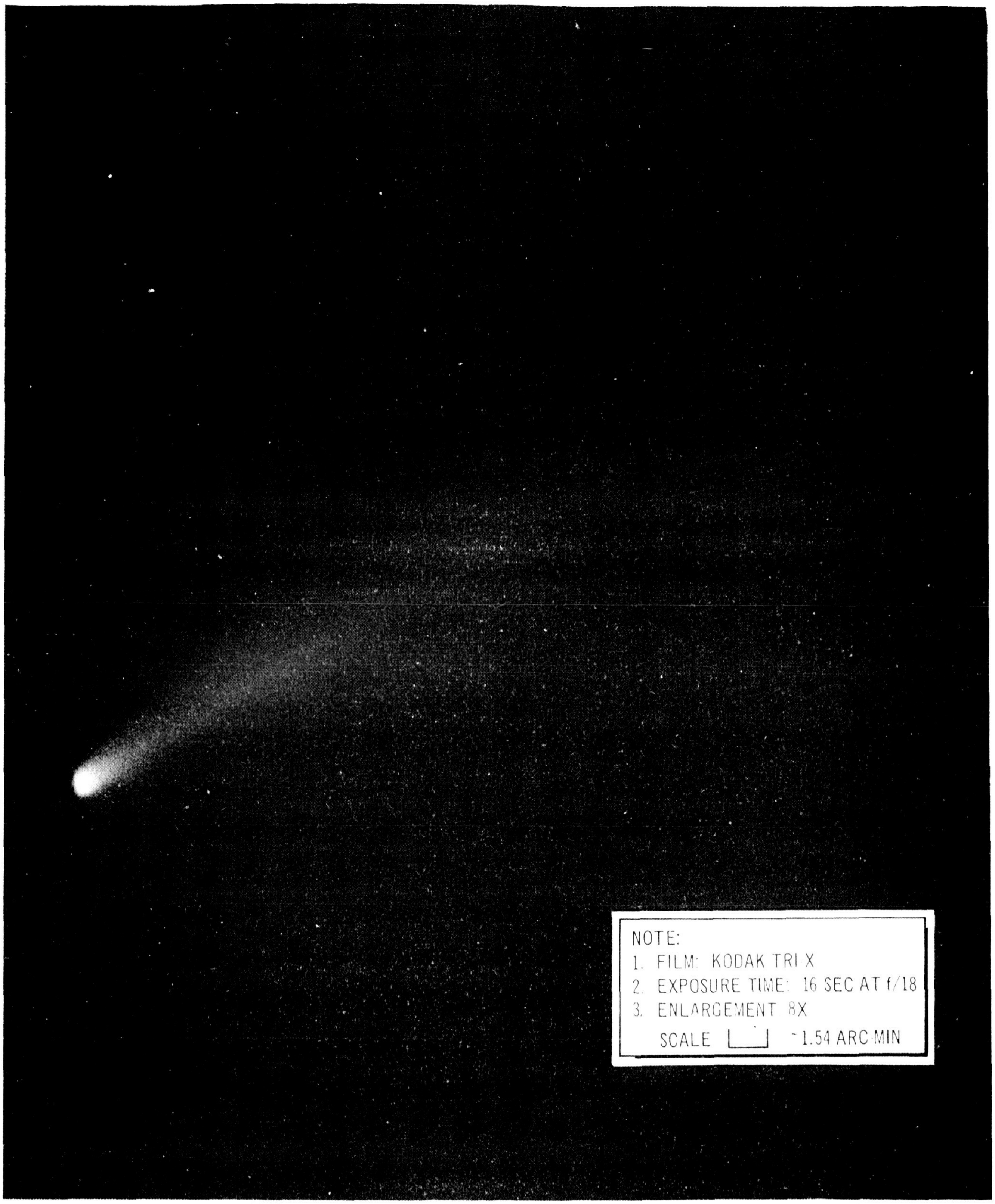


Figure 6-3A. Photograph of Comet Ikeya-Seki on 25 October 1965 at 15:29 UT

Figure 6-3B. Photograph of Comet Ikeya-Seki on 25 October 1965 at 15:29 UT
(Negative has been Fluor-O-Dodged)

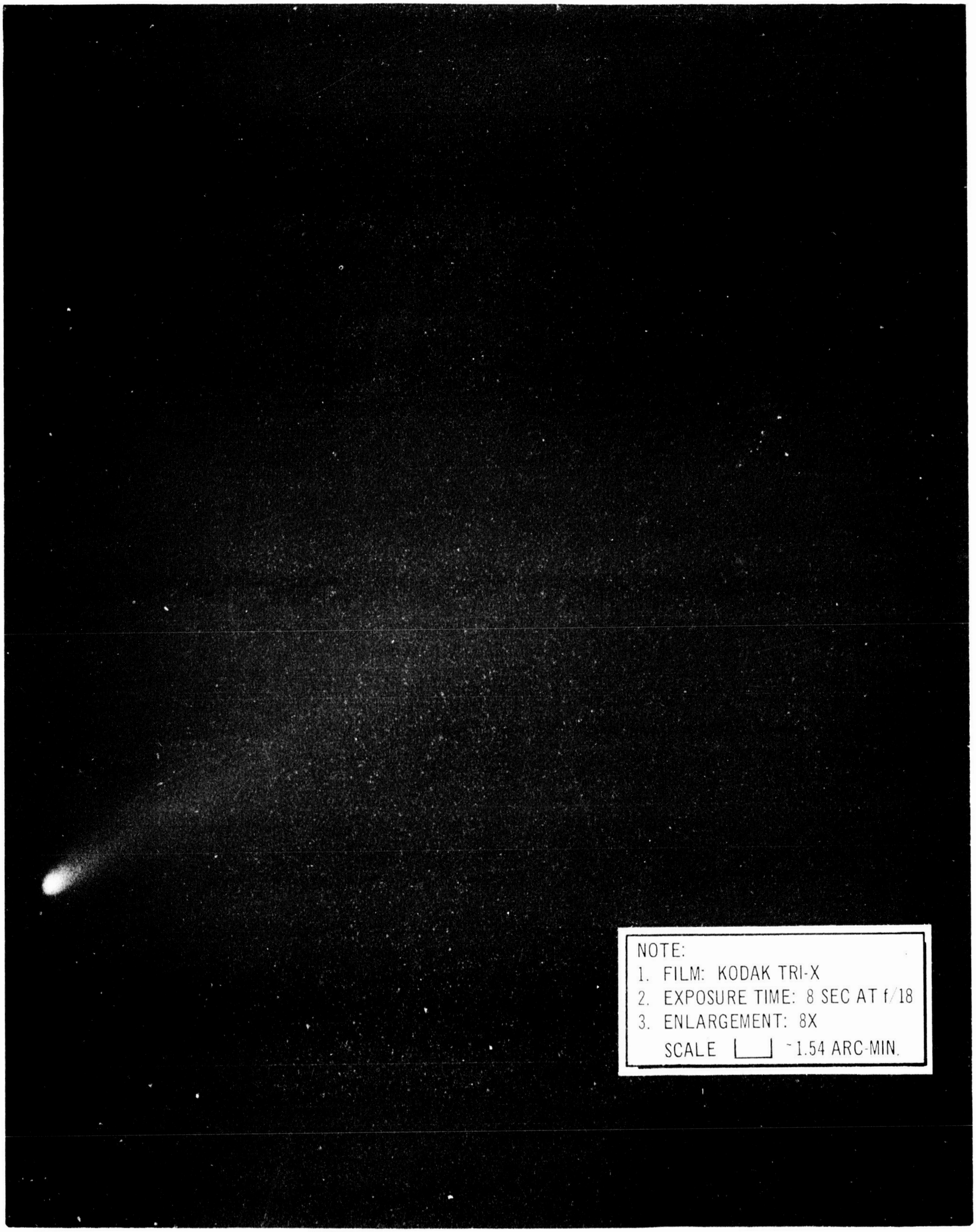


Figure 6-4A. Photograph of Comet Ikeya-Seki on 25 October 1965 at 15:30 UT

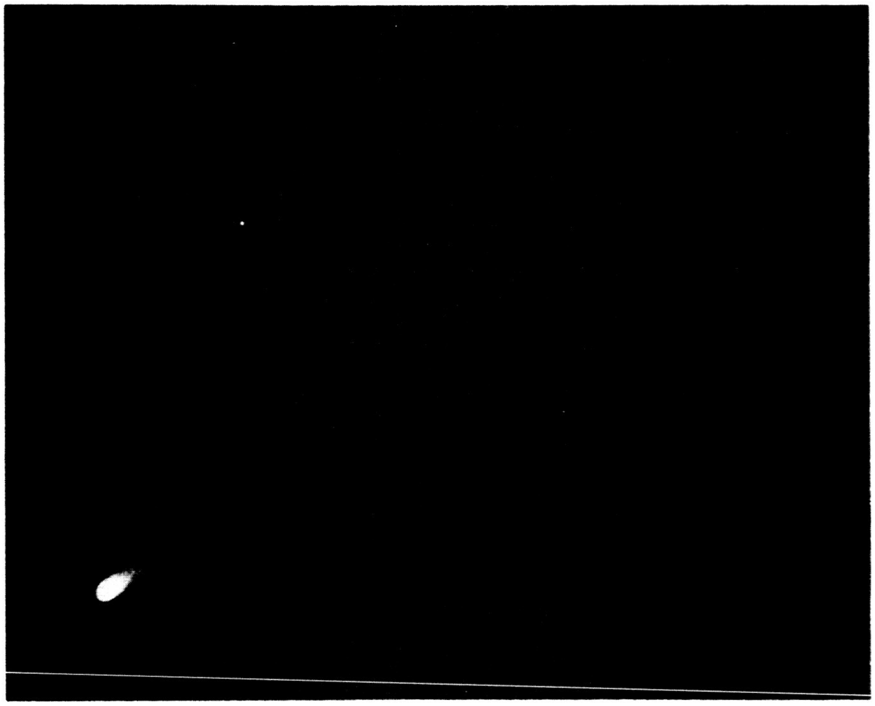


Figure 6-4B. Photograph of Comet Ikeya-Seki on 25 October 1965 at 15:30 UT (Negative has been Fluor-O-Dodged)

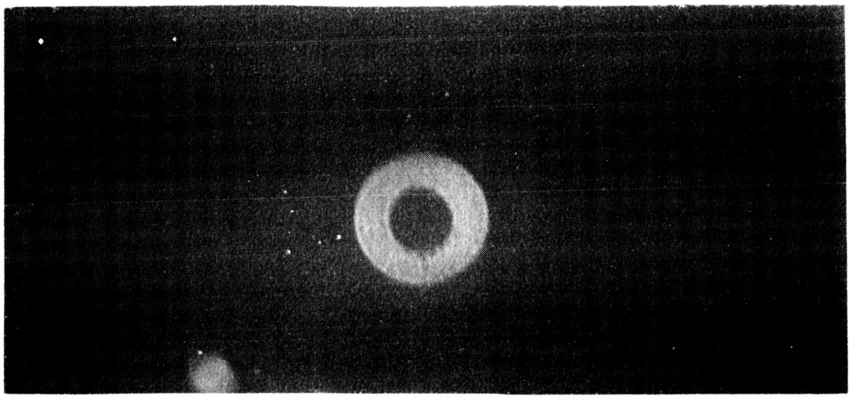


Figure 6-5A.

NOTE.
1. ENLARGEMENT: 4X
2. EXPOSURE TIME: 1 SEC AT f/16
3. FILM: KODAK PLUS-X

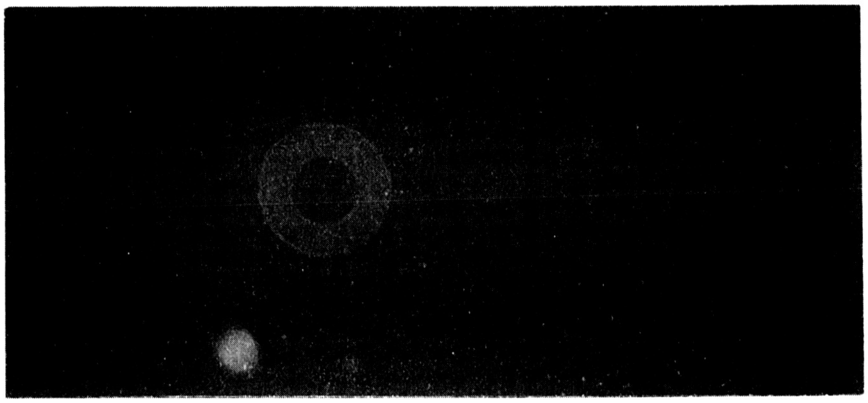
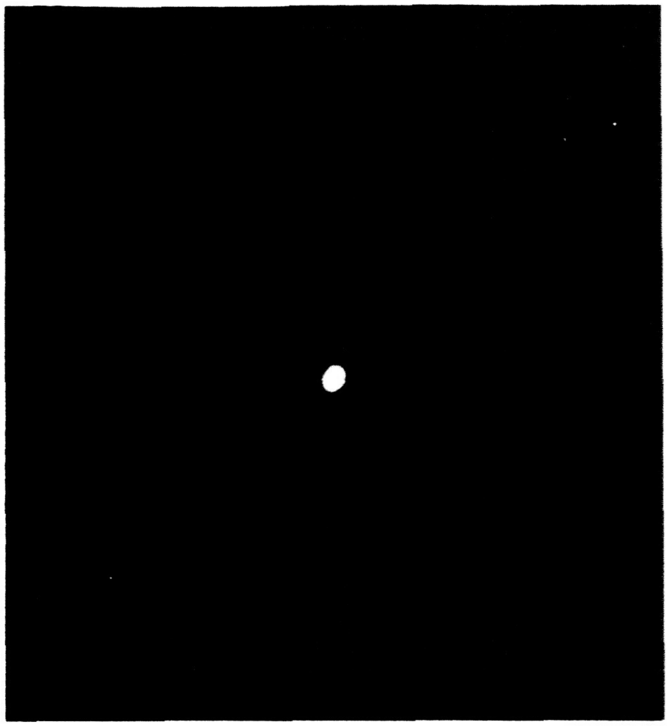


Figure 6-5B.

NOTE:
1. ENLARGEMENT: 4X
2. EXPOSURE TIME: 1/2 SEC AT f/16
3. FILM: KODAK PLUS-X

Figure 6-5. Photographs of Out-of-Focus Image of Venus Taken from NASA-Ames Convair 990 Jet Aircraft on 21 October 1965 at 05:32 UT were thought to be in focus but which showed that for exposures of less than 1/4 sec there were small holes in the centers of the images (Figure 6-6).



NOTE:
1. FILM: KODAK PLUS-X
2. EXPOSURE TIME: 1/8 SEC AT f/16
3. ENLARGEMENT: 9X

Figure 6-6. Photograph of Venus Taken from NASA-Ames Convair 990 Jet Aircraft on 21 October 1965 at 05:25 UT

It was planned to gain some information on the reduction of skylight background by photographing a suitable celestial image from various altitudes. Unfortunately, conflicting flight problems prevented this accomplishment.

6.3 ANGULAR SEPARATION BETWEEN CELESTIAL OBJECT AND SUN

The telescope system used on this expedition permitted taking photographs of the comet in visible light prior to sunrise whenever the elevation angle of the comet was greater than 10° or 11° at sunrise. When the comet elevation angle was less than 10° or 11°, the intense twilight was scattered by the optical window and heliostat mirror, causing washout of the comet image. At one time, the comet was followed for 42 min. after sunrise (separation angle between the sun and the comet was 9.4°); however, a sodium-D filter was required to suppress the sky background. The present unshielded airborne telescope system resulted in negligible gain in skylight reduction at altitude because of increased scattered light off the optics for daytime observations close to the sun.

It was evident from the above experience that observation of the cusp extension of Venus (Reference 2) during inferior conjunction (best observed when the separation angle between the sun and Venus is less than approximately 10°) with the present unshielded airborne telescope system might best be done when the sun is below the horizon and Venus is above. However, the short photographic time interval between Venus rise (Venus set) and sunrise (sunset), and the problem of twilight being scattered by the optical window and heliostat mirror present difficult problems to airborne observation of Venus. Obtaining the necessary light shielding for the optics presents a formidable problem. However, airborne observation of Venus, or any other celestial body, in the night sky continues to have advantages over ground-based observations by reducing astronomical seeing and atmospheric attenuation problems.

6.4 PHOTOGRAPHIC EXPOSURE

An examination of the moon photographs taken at an altitude of approximately 38,000 to 39,000 ft provides some measure of the time exposure required to obtain reasonable image quality. Examination of the cusps of the moon in the photographs (Figures 6-7A, 6-7B, and 6-7C) indicates some image improvement was achieved by reducing the exposure time from 1 sec to 1/2 or 1/4 sec. The double image in the upper cusp of Figure 6-7A was probably caused by aircraft motion in the unstabilized axis (that is, the axis of rotation around the line of sight). Improvement in the image quality between 1/2-sec (Figure 6-7B) and 1/4-sec (Figure 6-7C) exposure is not apparent; however, some improvement can be noticed in a comparison of Figures 6-8A and 6-8B. A decrease in the exposure from 1/4 to 1/8 sec does not noticeably improve the image quality (Figures 6-8B and 6-8C). Additional data to support the exposure study were obtained from the photographs of Venus (gibbous phase) made on the evening flight of 20 October. With respect to image motion, the image quality was also improved when the exposure was reduced from 1 to 1/2 sec. However, additional decrease in the exposure from 1/2 to 1/4 sec does not noticeably improve the image quality (Figures 6-9A, 6-9B, 6-9C and 6-6).

For the specific flight conditions at the time the moon and Venus photographs were made, a reasonable image quality was attainable with exposures at 1/2 sec and less. However, most of the comet photographs required exposures greater than 1/2 sec. For additional discussion of the stability on the stabilization system, refer to Section 2.

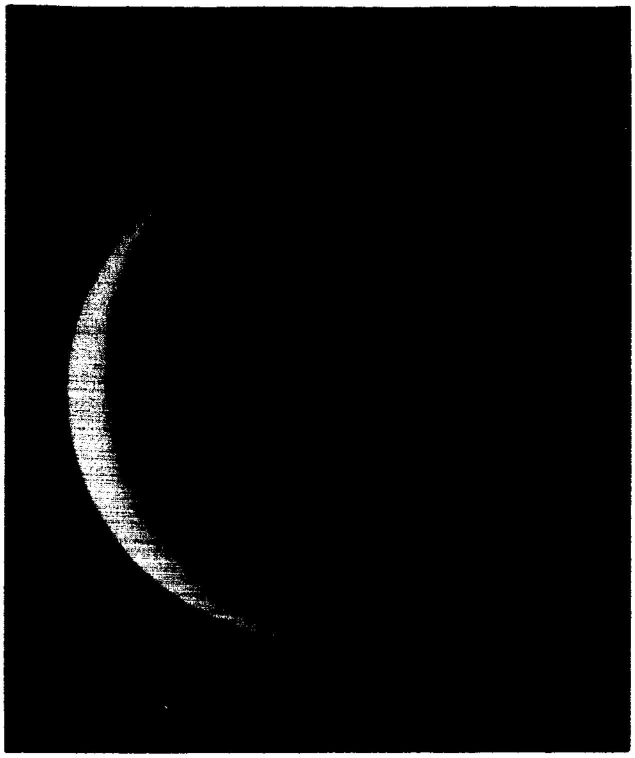


Figure 6-7A. Exposure Time: 1 Sec at f/16

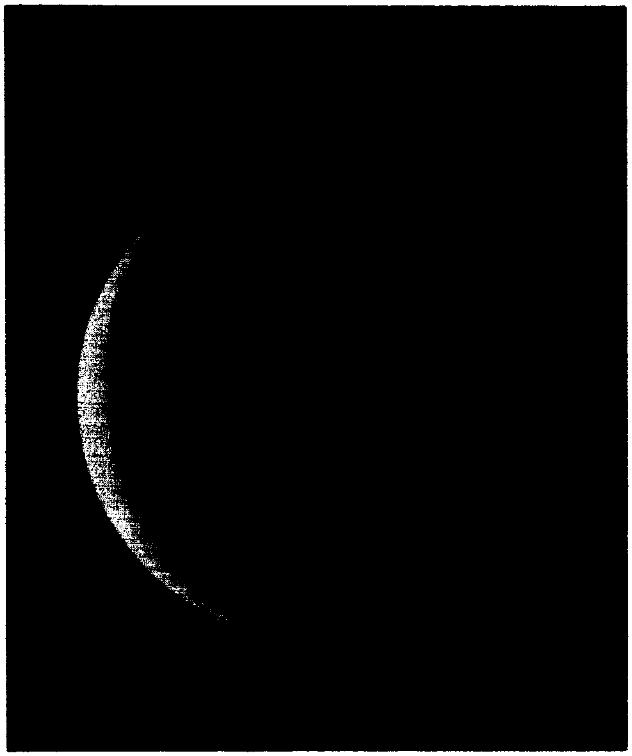


Figure 6-7B. Exposure Time: 1/2 Sec at f/16

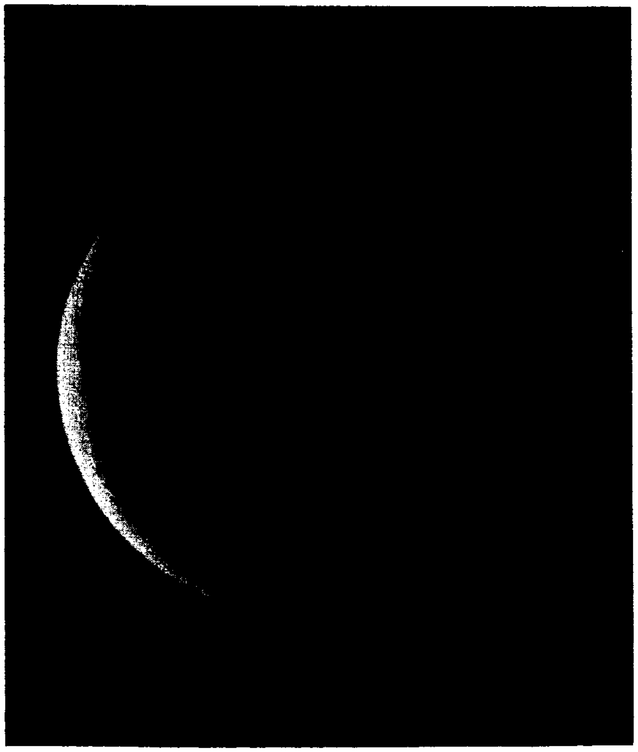


Figure 6-7C. Exposure Time: 1/4 Sec at f/16

NOTE:
1. FILM: KODAK PLUS-X
2. ENLARGEMENT: 7X

Figure 6-7. Photographs of Moon Taken from NASA-Ames Convair 990 Jet Aircraft on 21 October 1965 at 14:44 UT

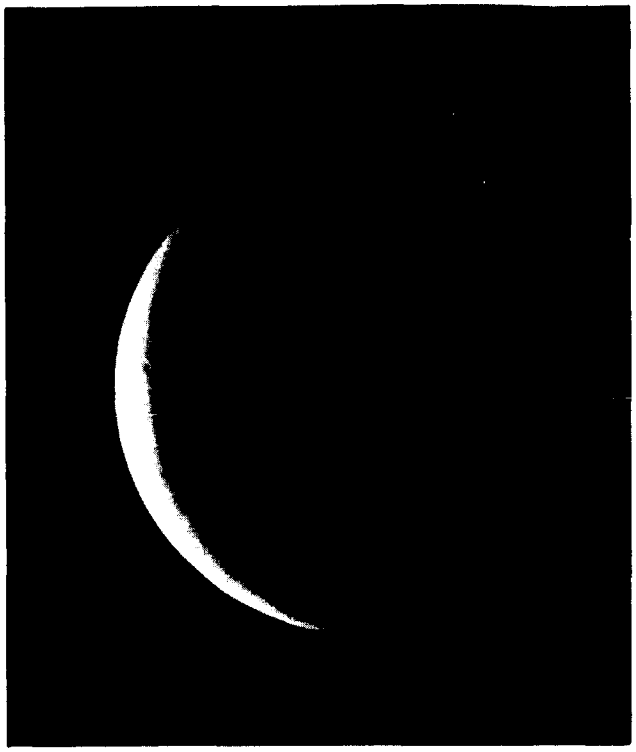


Figure 6-8A. Exposure Time: 1/2 Sec at f/16

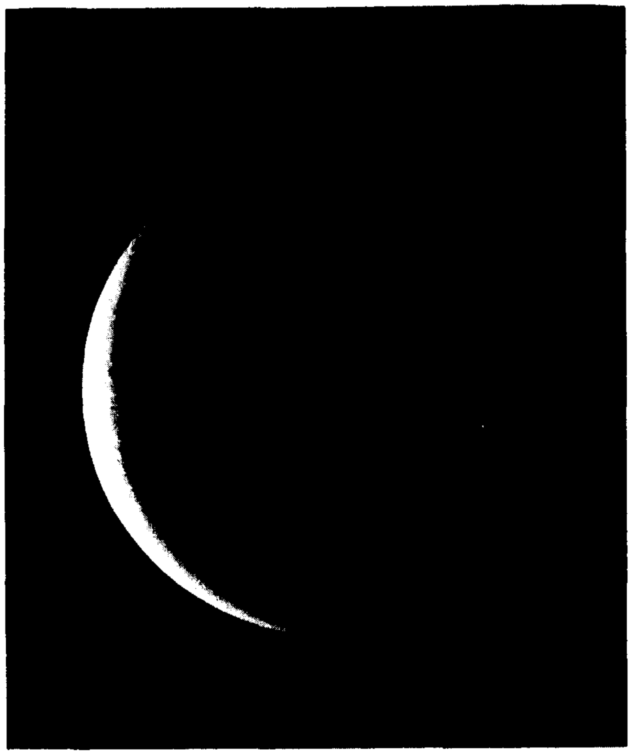


Figure 6-8B. Exposure Time: 1/4 Sec at f/16

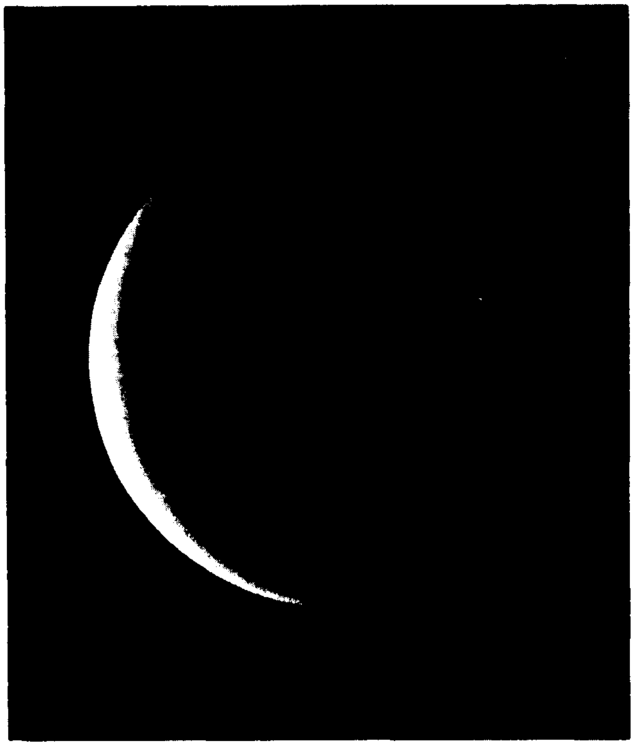


Figure 6-8C. Exposure Time: 1/8 Sec at f/16

NOTE:
1. FILM: KODAK PLUS-X
2. ENLARGEMENT: 7X

Figure 6-8. Photographs of Moon Taken from Convair 990 Jet Aircraft on 21 October 1965 at 15:00 UT

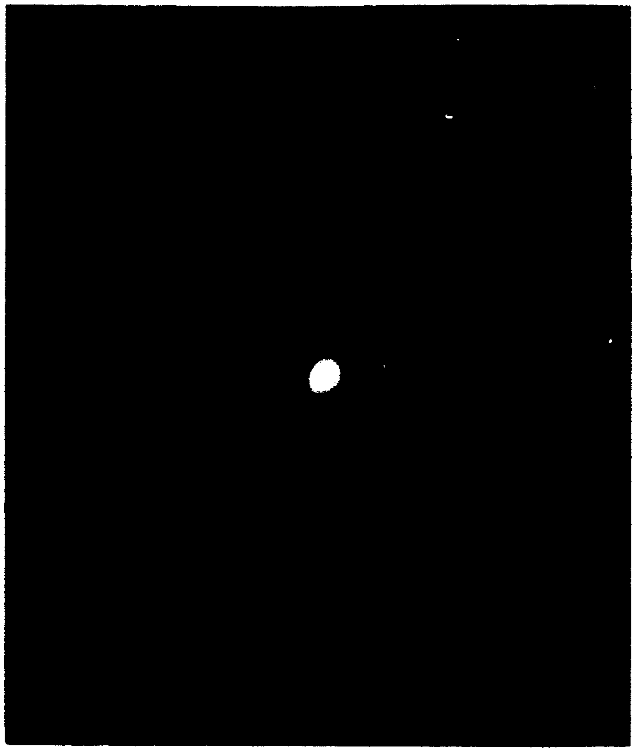


Figure 6-9A. Exposure Time: 1 Sec at f/16

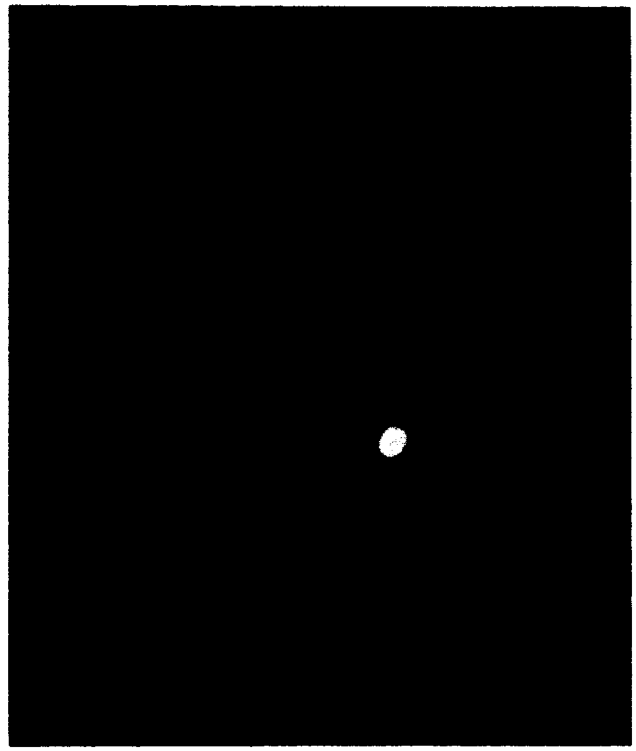


Figure 6-9B. Exposure Time: 1/2 Sec at f/16

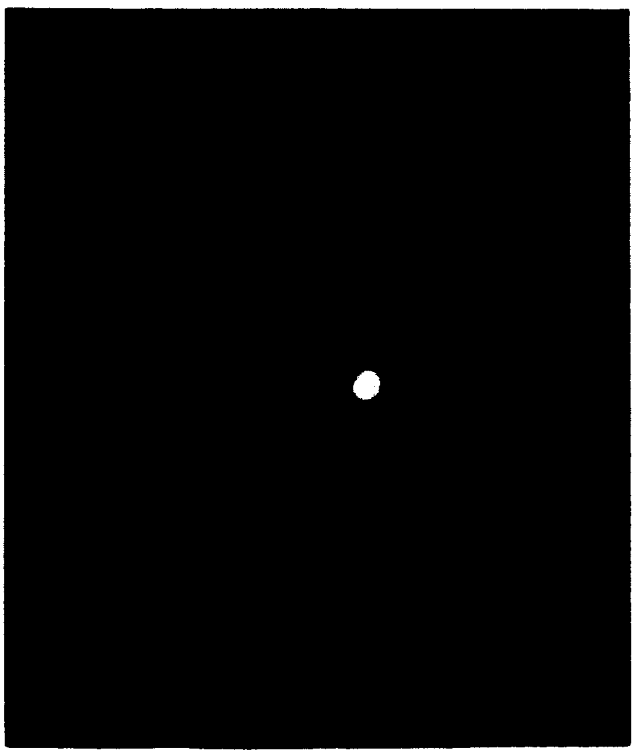


Figure 6-9C. Exposure Time: 1/4 Sec at f/16

NOTE:
1. FILM: KODAK PLUS-X
2. ENLARGEMENT: 9X

Figure 6-9. Photographs of Venus Taken from NASA-Ames Convair 990 Jet Aircraft on 21 October 1965 at 05:25 UT (Semidiameter of Venus was 9.74 arc-sec; Stellar Magnitude was −3.8)

Section 7

CONCLUSIONS AND RECOMMENDATIONS

The conclusions regarding the comet are as follows:

1. The tail of the comet increased in length from approximately 5 arc-min. on 17 October 1965 (before perihelion) to between 8 and 11 arc-deg after perihelion.
2. Photographs after perihelion showed band structure in the tail of the comet.
3. No separation of the comet's nucleus was evident through 26 October 1965.
4. The comet was observed to have a strong sodium D emission line.

The conclusions regarding airborne astronomical observations are as follows:

1. With the present stabilization system coupled to the Questar telescope, no obvious image smear of either the moon or Venus occurred when exposures of about 0.5 sec and less were used. Longer exposures resulted in obvious image deterioration.
2. Because of the intense skylight near the sun and the scattered light off the optical window and stabilization mirror, photography of a celestial object near the sun is a major problem with the present unshielded optical system. Therefore, photographic observations of Venus, when the separation angle between the sun and Venus is greater than 10°, might best be made when the sun is below and Venus is above the horizon. Observations of Venus with the current telescope system do not seem feasible when the separation angle is less than 10°.
3. Airborne observations of celestial objects in the night sky have advantages over ground-based observations by reducing the problems of astronomical seeing and atmospheric attenuation.

The recommendations regarding airborne astronomical observations are as follows:

1. The airborne telescope system should be insulated from aircraft vibration.

2. Third-axis stabilization (axis of rotation around the line of sight) should be considered if exposures greater than 1/2 sec are to be made of celestial objects of extended field of view (such as the moon).

3. The proposed airborne program (Reference 2) to perform cusp observations of Venus does not seem justified at this time, because of the limitations of the current optical system.

4. Observations of the band structure of Venus, which are observed in ultraviolet light, or observations of the cusp extensions of Venus could best be achieved by eliminating atmospheric interference. This could be done by observation of Venus from satellite altitudes with a narrow field-of-view telescope shielded against direct sunlight. This experiment could probably be performed from a space vehicle such as the Apollo spacecraft.

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