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SOME RESULTS AT SMITHSONIAN OBSERVING STATIONS

by

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STATISTICS ON CLOUD COVER AT BAKER-NUNN OBSERVING SITES[1]

by

Peter Brand[2] and Leonard Solomon[3]

Satellite photography at Baker-Nunn camera stations is based on predictions computed in Cambridge and sent to each station. The predictions generally are evenly grouped in evening and morning hours, with lower density in the midnight sky. It is rare, however, for the midnight hours to be completely devoid of predictions. The number of predictions varies from 15 to 35 per station per night.

The "Percent Not Attempted Due to Clouds" given here refers to those predicted satellite transits for which no film was exposed because of obscuring clouds in the sky area of interest. This is a lower limit to the actual cloud cover hindrance, as satellite photography is occasionally attempted through thin or broken clouds.

Statistics for ten of the stations are presented here, covering the years 1962 and 1963. Data for 1964 is not yet complete in this form.

[1]This work was supported in part by grant NsG 87-60 from the National Aeronautics and Space Administration.

[2]Mechanical Engineer, Station Operations Division, Smithsonian Astrophysical Observatory.

[3]Astronomer, Station Operations Division; Chief, Data Division, Smithsonian Astrophysical Observatory.

Table 1.--Percent not attempted due to clouds

Station Coordinates		Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
New Mexico		1962	36	25	27	15	5	12	49	32	48	19	26	22
253° 27'(E)	+32° 25'	1963	34	27	21	29	30	13	48	57	28	16	27	17
South Africa		1962	42	29	31	26	4	6	1	5	8	29	53	37
028° 15'(E)	-25° 58'	1963	50	23	27	28	15	21	20	2	7	30	55	49
Australia		1962	32	21	21	9	34	12	22	22	27	38	15	18
136° 46'(E)	-31° 06'	1963	16	22	22	22	51	35	47	21	18	17	18	22
Spain		1962	52	32	81	43	33	15	21	15	34	47	40	43
353° 48'(E)	+36° 28'	1963	72	49	39	39	35	32	4	19	22	19	60	45
Peru		1962	81	71	56	38	10	2	5	6	35	22	42	55
288° 30'(E)	-16° 28'	1963	88	95	63	56	23	2	6	15	21	26	13	52
Iran		1962	28	44	33	54	10	1	18	16	03	nil	14	38
052° 31'(E)	+29° 38'	1963	17	40	30	47	30	7	15	23	1	12	35	22
Curaçao		1962	52	43	56	53	74	66	46	38	60	39	45	50
291° 10'(E)	+12° 05'	1963	70	59	51	68	70	40	64	55	63	50	65	62
Florida		1962	55	40	62	55	36	61	41	55	52	45	55	43
279° 53'(E)	+27° 01'	1963	57	58	47	28	50	42	44	29	49	32	49	43
Argentina		1962	53	52	38	72	51	27	39	32	22	29	35	43
294° 54'(E)	-31° 57'	1963	*	35	40	27	39	33	36	32	57	46	46	30
Hawaii		1962	23	41	56	39	33	5	38	18	20	16	26	33
203° 45'(E)	+20° 43'	1963	59	17	70	78	52	28	29	23	39	39	32	30

*No photography attempted for a 3 week period when the mirror was removed for realuminizing.

N65-31270

RESIDUALS IN FIELD-REDUCED OBSERVATIONS[1]

by

Leonard Solomon[2]

We have compared field-reduced observations with photoreduced observations and the orbits derived from them to determine the approximate error to be expected in any field-reduced observations. This was done as a comparison with previously estimated values. Four periods of coverage of roughly one month each in 1962 and 1963 were taken, two of 1960 ι2, one each of 1961 αδ1 and 1959 α1. Photoreduced observations were used to derive the best possible orbits. We then used the same orbits as a standard and found new residuals of the same photoreduced observations along with the same period's field-reduced observations, station by station. By using *a priori* low weight for the field-reduced data, their effect on the orbit was made negligible.

As a measure of the precision of each field measurement we take the difference between precisely-reduced and field-reduced residual($|\sigma_f - \sigma_p|$), where the observations are made within one minute of one another (i.e., on the same film). Each such difference is given unit weight in computing the mean, with the value used in each case being taken when the observations were closest to epoch for the particular orbit determination set. Table I shows the results for all Baker-Nunn stations. Note that the estimated error is quite close to the estimated BD chart plotting error of 1 minute of arc; hence we can now state that field-reduced accuracies are at least partially limited by chart accuracy.

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[1]This work was supported in part by grant NsG 87-60 from the National Aeronautics and Space Administration.

[2]Chief, Data Division; Astronomer, Station Operations Division, Smithsonian Astrophysical Observatory.

Table 1.--Residuals--Field minus precisely-reduced

Station	No. Obs.	Δ Dec	Δ R.A.
1	60	56".6	63".3
2	76	64.1	62.3
3	71	51.8	58.2
4	67	57.4	62.1
5	14	54.3	79.7
6	41	49.1	65.1
7	28	67.0	90.2
8	38	63.8	71.8
9	40	62.4	50.2
10	44	62.8	60.6
11	72	72.2	61.7
12	28	68.5	59.4
Total	579	60.9 ± 7.0	63.4 ± 10.8

PHOTOGRAPHY OF CHEMILUMINESCENT STUDIES OF UPPER ATMOSPHERE WIND PHENOMENA[1]

by

John Mazzotta[2], Roy Proctor[3], and James Latimer[4]

Abstract.--Several of the SAO Satellite Tracking stations have participated in studies of upper atmosphere wind phenomena through the use of rocket-released chemiluminescent trails. Using the results of early attempts, station personnel have devised new techniques for photographing these trails.

Introduction

In recent years, a variety of experiments have been conducted in an international effort to study upper atmosphere wind phenomena. To investigate properties such as wind velocities, shear, turbulence, and diffusion, rocket-borne devices capable of creating visible trails in the atmosphere have been perfected. Sodium vapors and trimethylene aluminum are two agents used to create these trails. The former is effective only during twilight, roughly 20 to 40 minutes at sunrise and sunset, when the cloud is illuminated by the sun against the dark background of the sky. The latter, on the other hand, generates a visible trail under full night conditions.

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1 Supported by grant number NsG 87-60 from the National Aeronautics and Space Administration.

2 Observer, Hawaii, U.S.A.

3 Observer, Wallops Island, Virginia, U.S.A.

4 Observer, Argentina

Because of their proximity to various launch sites throughout the world, the Astrophysical Observing Stations of the Smithsonian Institution have been asked to participate in the program by obtaining Baker-Nunn photographs of the various chemical releases. Such services are expected under the provisions of agreements with some host countries, and the Observatory is always anxious to cooperate in worthy scientific experiments. This report includes the results obtained by the stations in Argentina and Hawaii, covering a series of shots conducted by the Argentine Space Commission and the Sandia Corporation, and the Wallops Island station. Each report outlines the techniques used, the problems encountered, and suggested solutions for overcoming these problems.

Sodium Cloud Experiment - Argentine Space Commission

The Argentine Space Commission conducted a series of three launches on 4, 5 and 6 November 1964, from Chamical in the province of La Rioja approximately 200 kms from Villa Dolores, the station site. The first launch, fired on 4 November, could not be photographed due to a solid cloud cover over the station site. However, photographs were obtained of the second and third launches which were conducted during evening and morning twilights, respectively.

The evening shot was photographed from 23:17:42, when the rocket's afterblast and the embryonic sodium trail first became visible, until 23:36:10, when the trails either dissipated or became invisible due to darkness. (See Figures 1, 2, and 3.) The morning shot was photographed from 08:34:32 until 08:50:52. More detailed information of the photography and the results is found in Table 1.

Approximately the first nine minutes of coverage by the Baker-Nunn camera produce results of good quality. The remainder, though of qualitative interest, will not be of sufficient contrast to give much quantitative information. It should be noted here that in each shot the time of launch directly affected the photographic results since the last half lost definition and contrast. This was due in part to expansion and diffusion, and in the case of the evening shot to lack of illumination as the twilight grew darker, and for the morning shot excess illumination as the twilight grew brighter.

In the evening firing, the rocket was sighted about one and one-half minutes after launch time, but the morning test was not visible until some two and one-half minutes after launching. Apparently the morning shot, unlike that of the evening, experienced a delay in sodium ejection until the rocket was practically out of the turbulent zone. The first frames of the morning shot show nothing but a "blob" at the top of the arc with no turbulence. For this reason the camera was moved to catch the descending column. Somewhat later, a different camera orientation showed turbulence in both the ascent and descent columns.

Two problems plague the operator constantly during the photography of an object such as this. The first is the size of the field to be photographed. At our range something in the order of $30^{\circ} \times 30^{\circ}$ would be ideal to give full, uninterrupted, stationary camera coverage of the entire experiment. With the $5^{\circ} \times 30^{\circ}$ field of the Baker-Nunn, there are several choices of orientation left to the operator; vertical orientation of the "ascent" column, vertical orientation on the "descent" column, or horizontal orientation across both columns. There are obvious disadvantages to each of these choices; for the vertical orientations horizontal movement can, and did, exceed five degrees, while for the horizontal orientation, the vertical area of interest is more than five degrees long.

The second problem concerns the proper exposure time, rate, diaphragm, and filter. This is, of course, something only experience and experimentation can determine. Based on the present results, the following is recommended. Assuming the one frame every eight seconds time interval is satisfactory to those making the measurements, the combination of a 16 cycle rate with an f/4 diaphragm using wratten 23A filters has enough latitude to give excellent results for sky conditions ranging from "bright" to "medium dark." For "dark" sky photography, more experimentation is needed without diaphragm or filter.

<u>Trimethylene Aluminum Shots - Sandia Corporation</u>

In conjunction with the Sandia Corporation, the Satellite Tracking Station on Maui employed the Baker-Nunn camera to photograph trimethylene aluminum released from two rockets launched on the island of Kauai (100 miles west of Maui). These launches were at 85 to 150 kms. The trimethylene aluminum which is released from canisters in the twilight hours, after the sun has set, gives a light greenish glow in twilight and a blue-white glow in darkness. Employment of the B-N camera with Royal-X Pan film in the twilight hours is necessarily limited to the use of filters (to improve the contrast between the cloud and the relatively bright twilight sky) and diaphragms (to prevent background fogging). Two diaphragms (f/4.0 and f/8.0) were prepared with Kodak red wratten A-23 filters; this was done with the intention of using the f/8.0 diaphragm and filter in the early twilight, using the f/4.0 diaphragm and filter in the late twilight, and using neither diaphragm nor filter in darkness.

The first shot, 06:18 Z on 1 November 1964, was photographed in complete darkness, three hours after the sun had set. It was photographed with Royal-X Pan film, Kodak batch 283353, at the 16-second cycle rate, with two transports per cycle, using neither diaphragm nor filter. The results were positive, yielding clear definition of the cloud with a good star background. (See Figures 4, 5, and 6.)

The second shot (Figures 6 and 7) occured at 04:30 Z on 3 November 1964, 75 minutes after the sun had set. The results of this photography with Royal-X Pan recording film, (SO-283) Kodak batch 35, indicate that good results may be obtained through the employment of the following schedule (when shooting into the setting sun). (See Table 2.) Note that times are computed on the basis of sunset at 03:15 Z.

The major problem in this photography is the selection of the proper camera settings, since no settings or look-angles were available. As seen from the tracking station, both rockets had parabolic trajectories. For the first shot, it was during the downward portion of the trajectory that the dense cloud was released (This was clearly distinguishable.). Three of the frames show the rocket releasing the cloud. The material is released in an arc which is apparently almost vertical to the horizon. As it is dispersed by the winds, it appears to move in bands approximately parallel to the horizon. As seen from the tracking station on Maui (elevation 10,000 feet and 100 miles distant from the origination of the launch), the cloud appeared between 20° and 30° above the horizon, almost due west. The second shot differed from the first in that the cloud was released during the upward portion of the trajectory; the release of the material was also clearly distinguishable in this case.

Details of the results of these shots are listed in Table 3. Two earlier launches were successful, but not photographed by the Maui Satellite Tracking Station, at 04:30 Z on 23 October 1964, and at 06:30 Z on 28 October 1964. The two launches which were photographed were cut short when fog rolled in on the station.

Chemiluminescent Photography - Wallops Island

Since December 1963 we have attempted photography on seven sodium launches, the results of which are listed in Table 4.

The successful plates of 5 and 6 November were sent to Dr. McCrosky, who forwarded them to Mr. Beddinger of the Geophysics Corporation of America. We have had no indication of whether the plates were useful to G.C.A. or not.

Through trial and error (mostly error) we have developed quite efficient observing techniques for the sodium rockets. This was made possible by improving our timing methods, modifying the SS and ST cameras, and using the rubberized camera cover (Baker-Nunn type). We can now load and unload the cameras in full daylight, with very little fogging of the film.

With accurate timing and two or more camera stations, we can now show the precise growth of the sodium cloud and reconstruct a three-dimensional model of the cloud from time of ejection until dispersion.

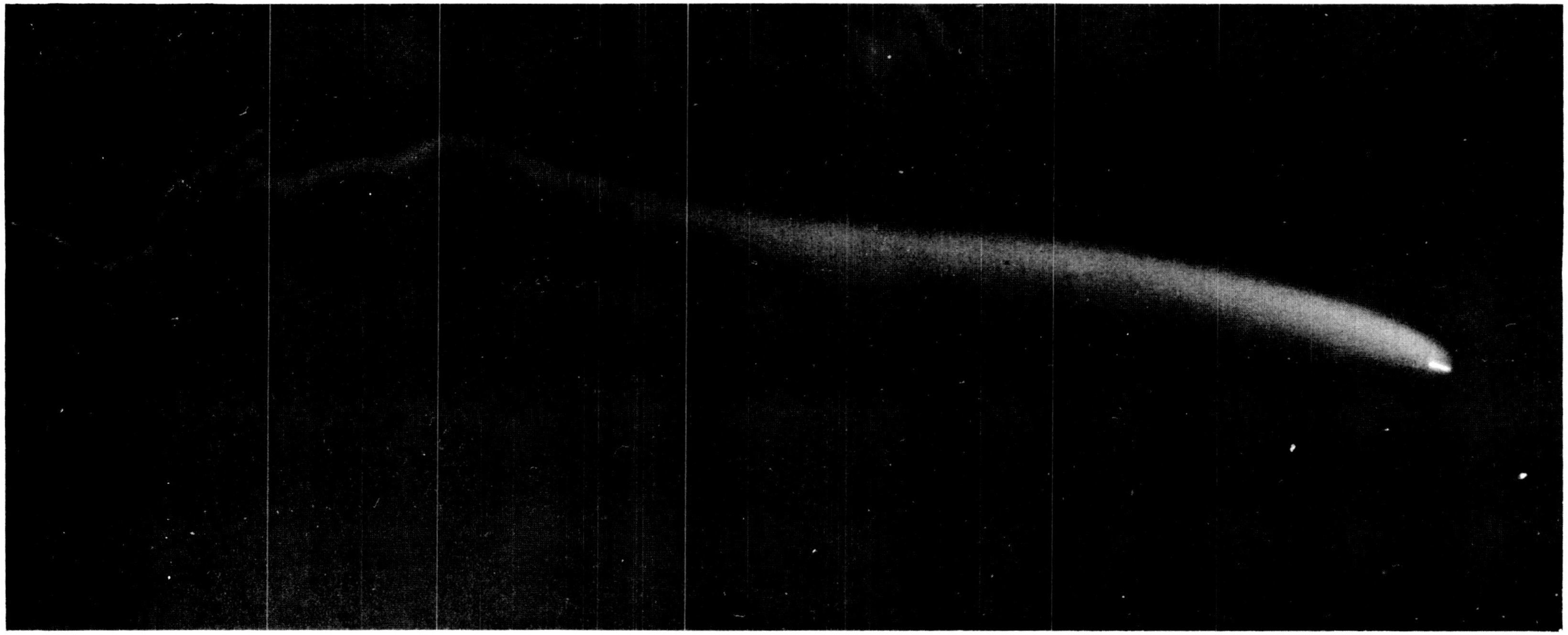

Figure 1.--Evening shot: rocket ascending and sodium trail contortions beginning.

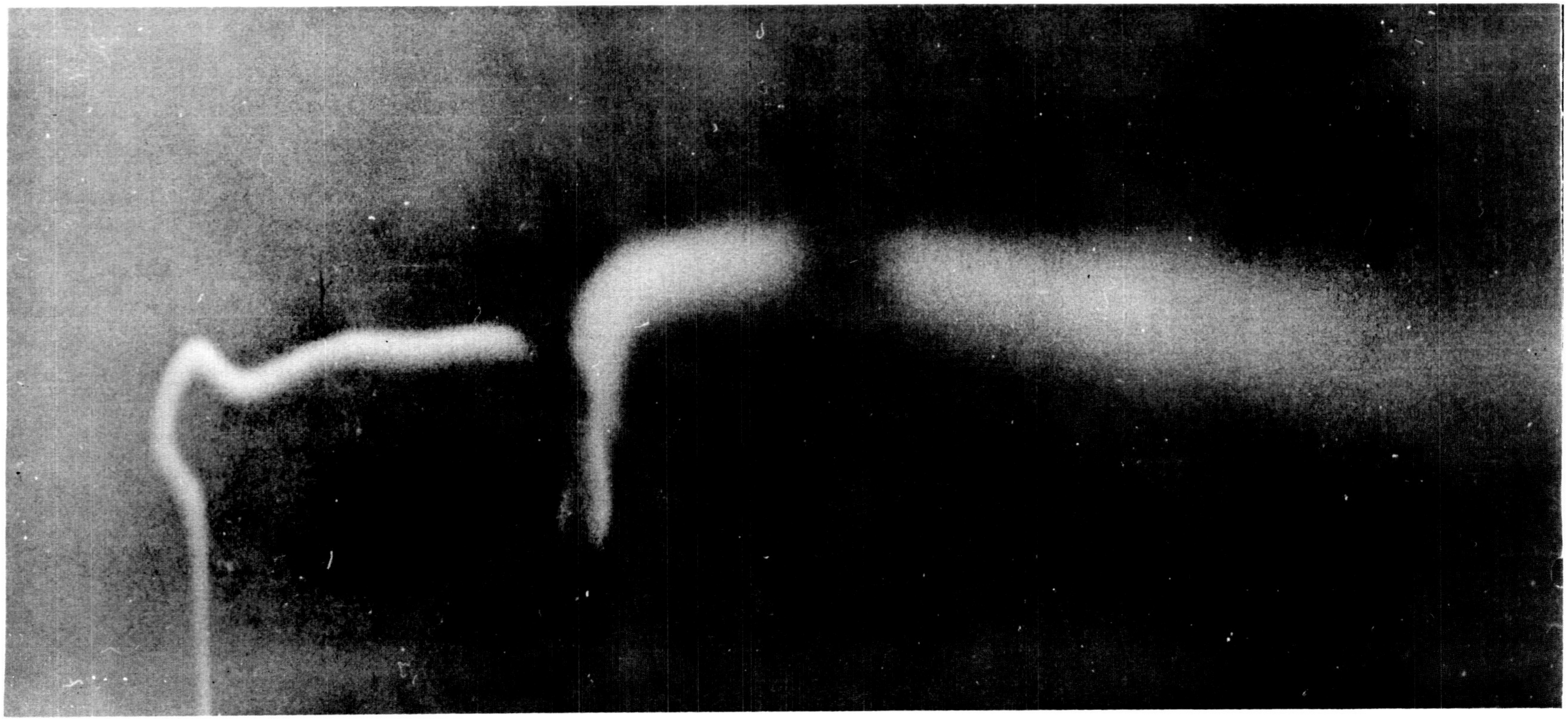

Figure 2.--Evening shot: same region a minute later.

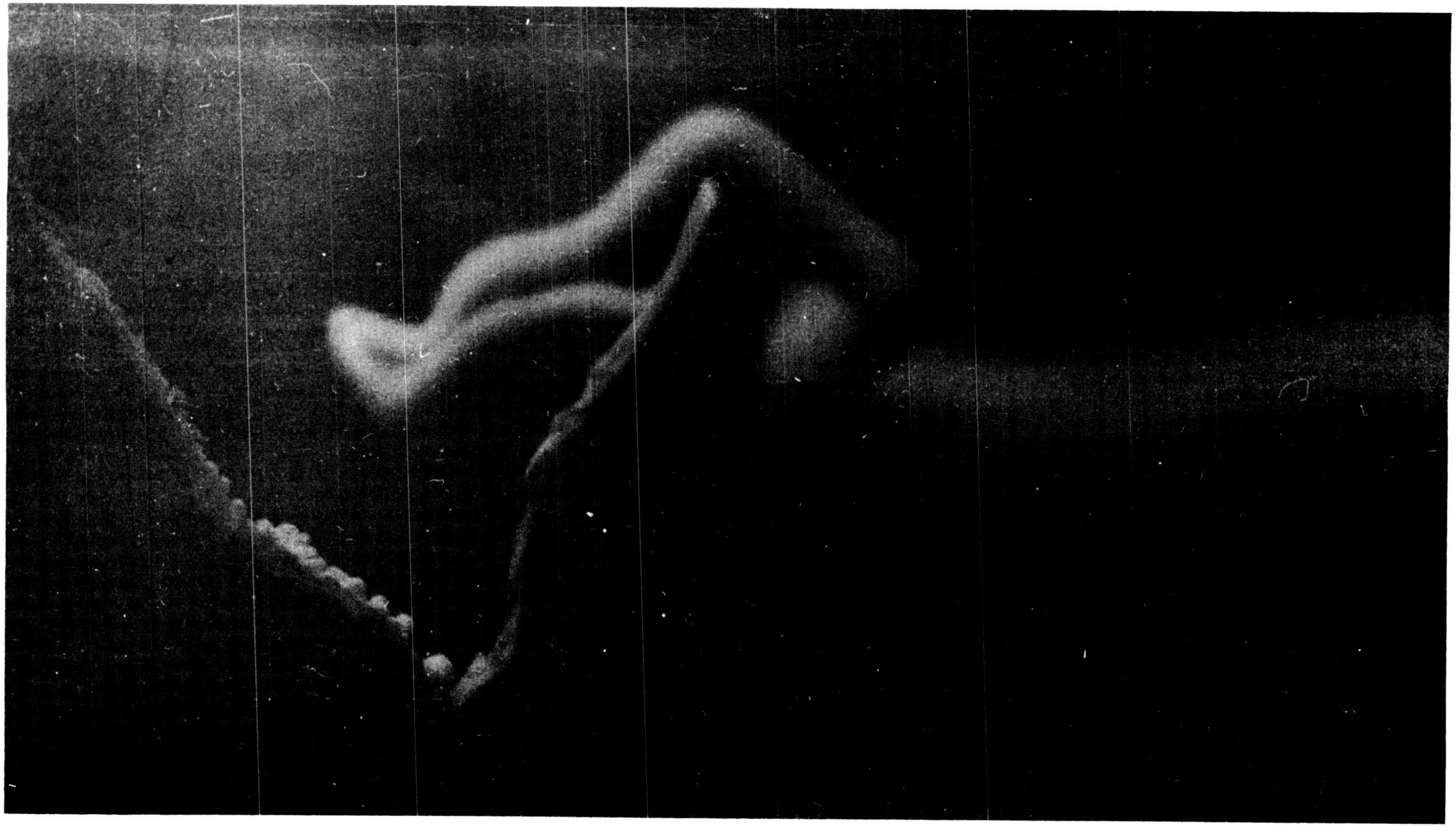

Figure 3.--Evening shot: turbulence in the ascending column.

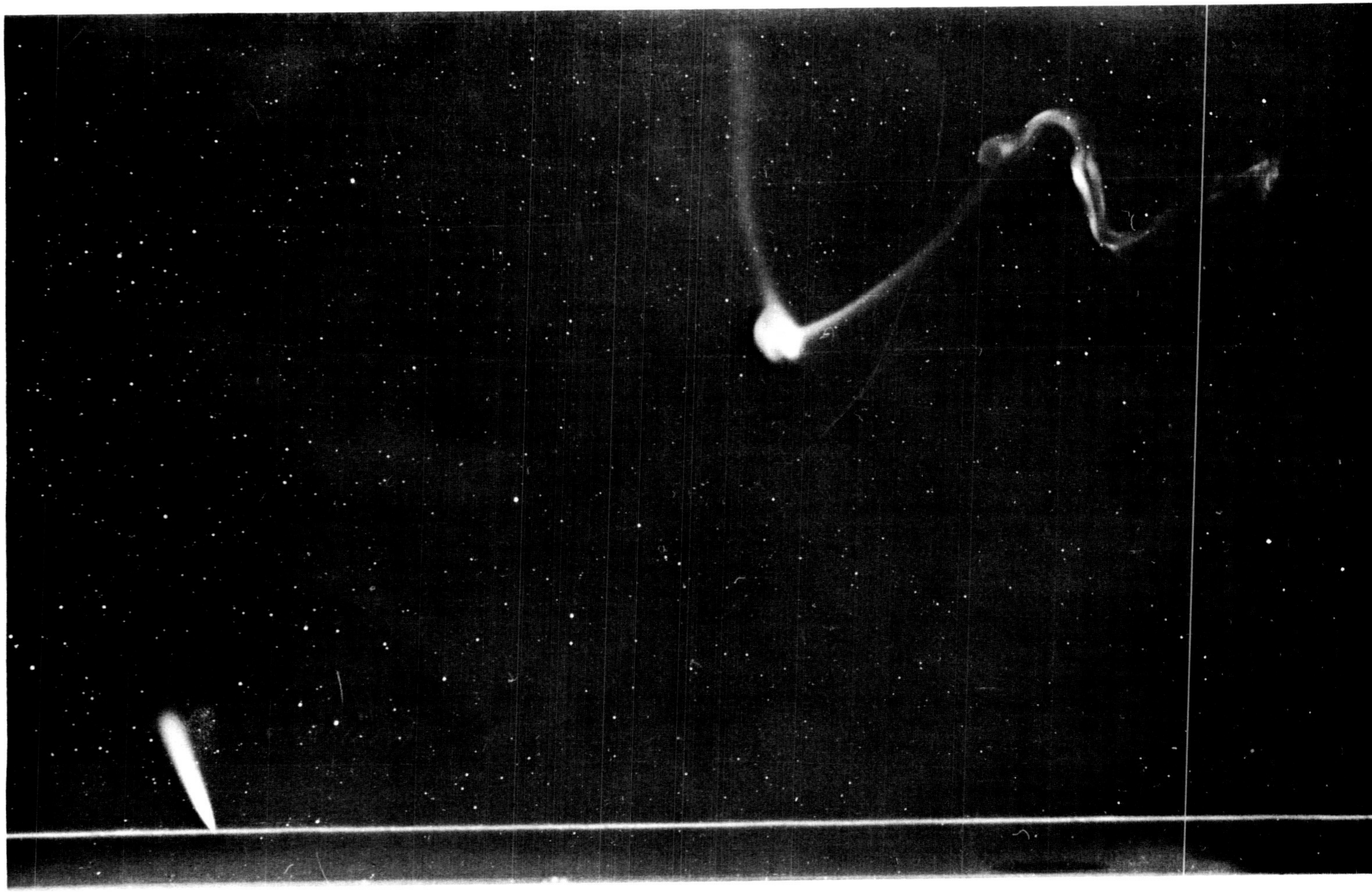

Figure 4.--Trimethylene aluminum shot of 1 November 1964 photographed at 06:22:14.

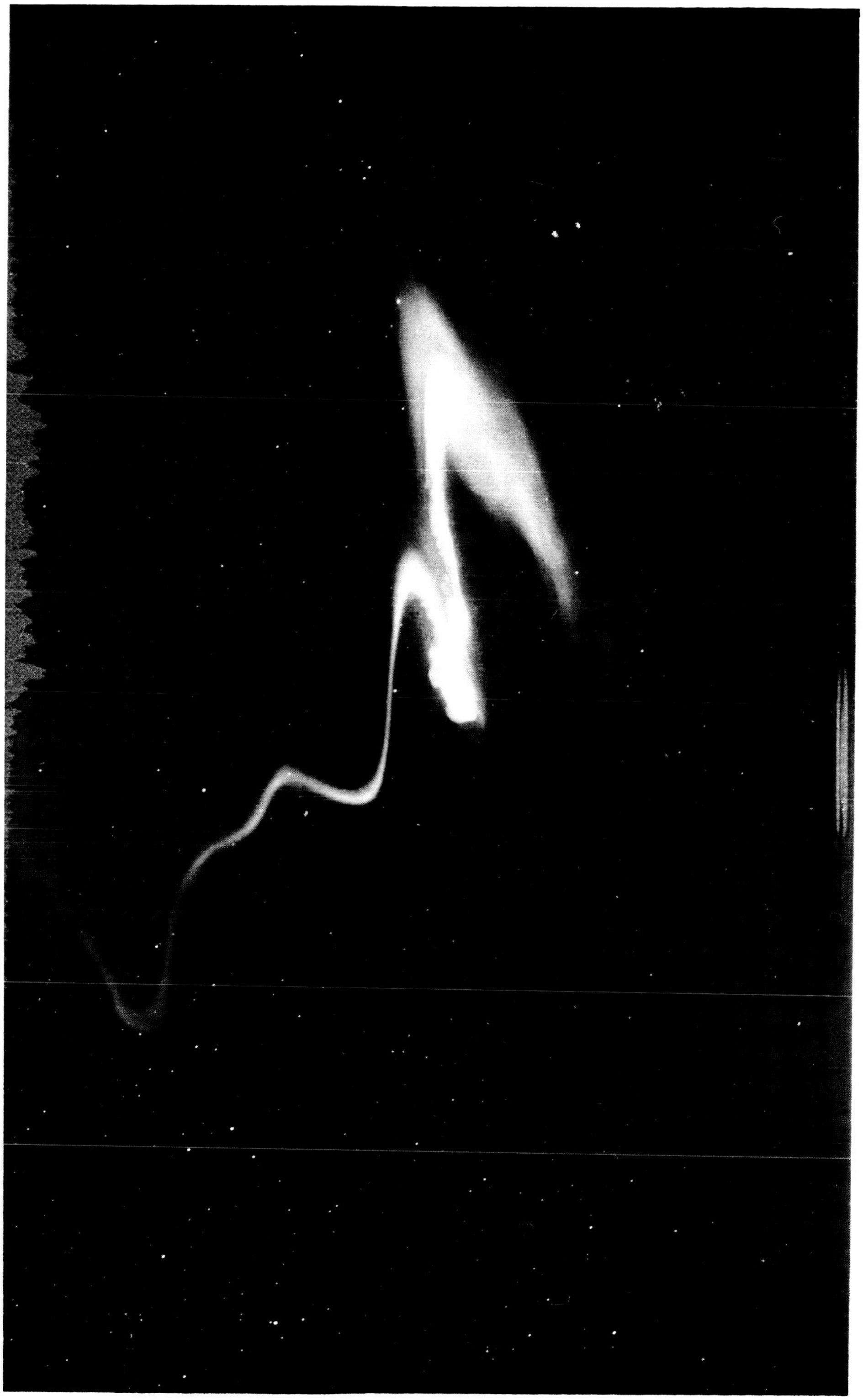

Figure 5.--Trimethylene aluminum shot of 1 November 1964 photographed at 06:26:59.

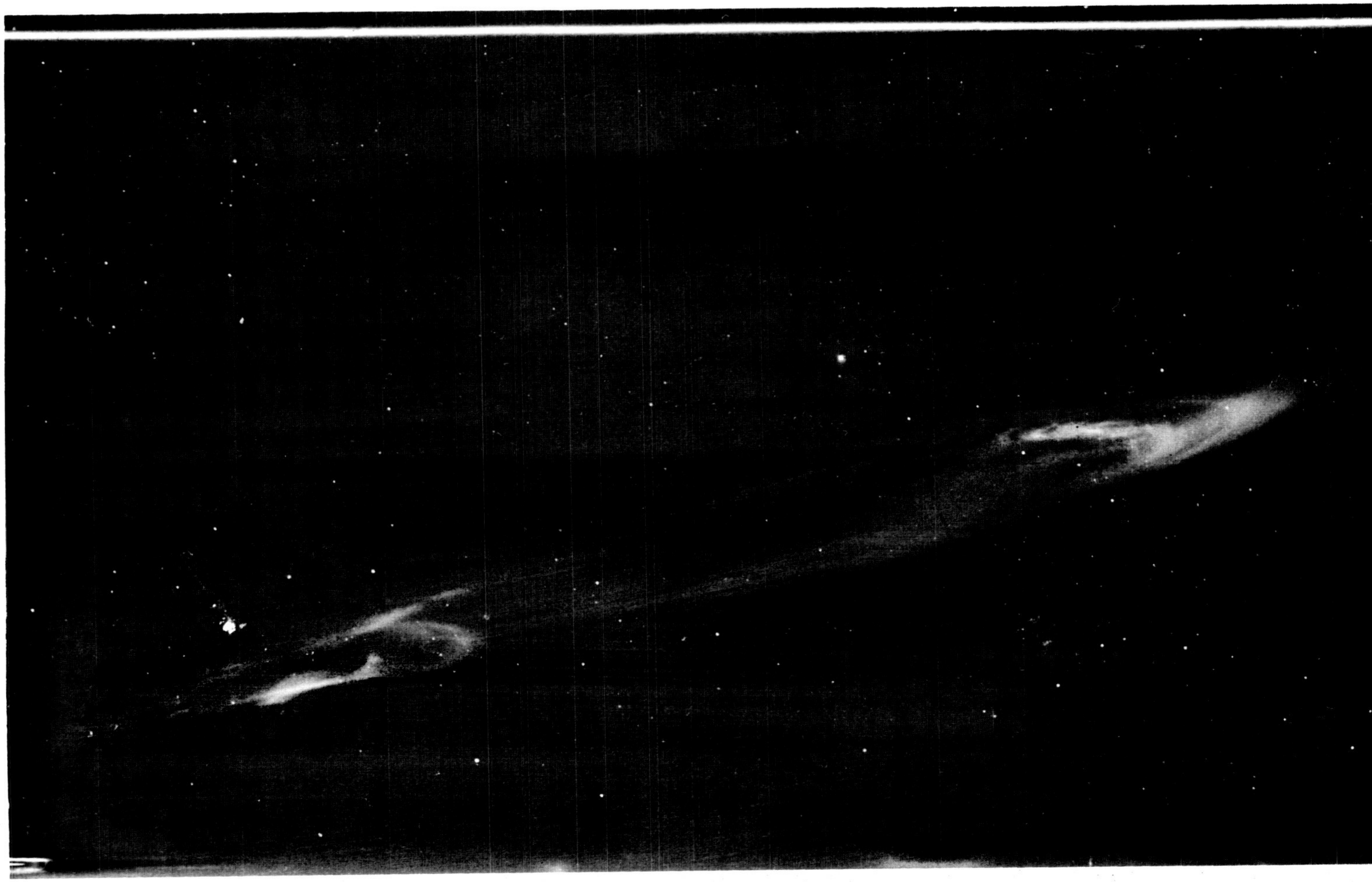

Figure 6.--Trimethylene aluminum shot of 1 November 1964 photographed at 06:39:47.

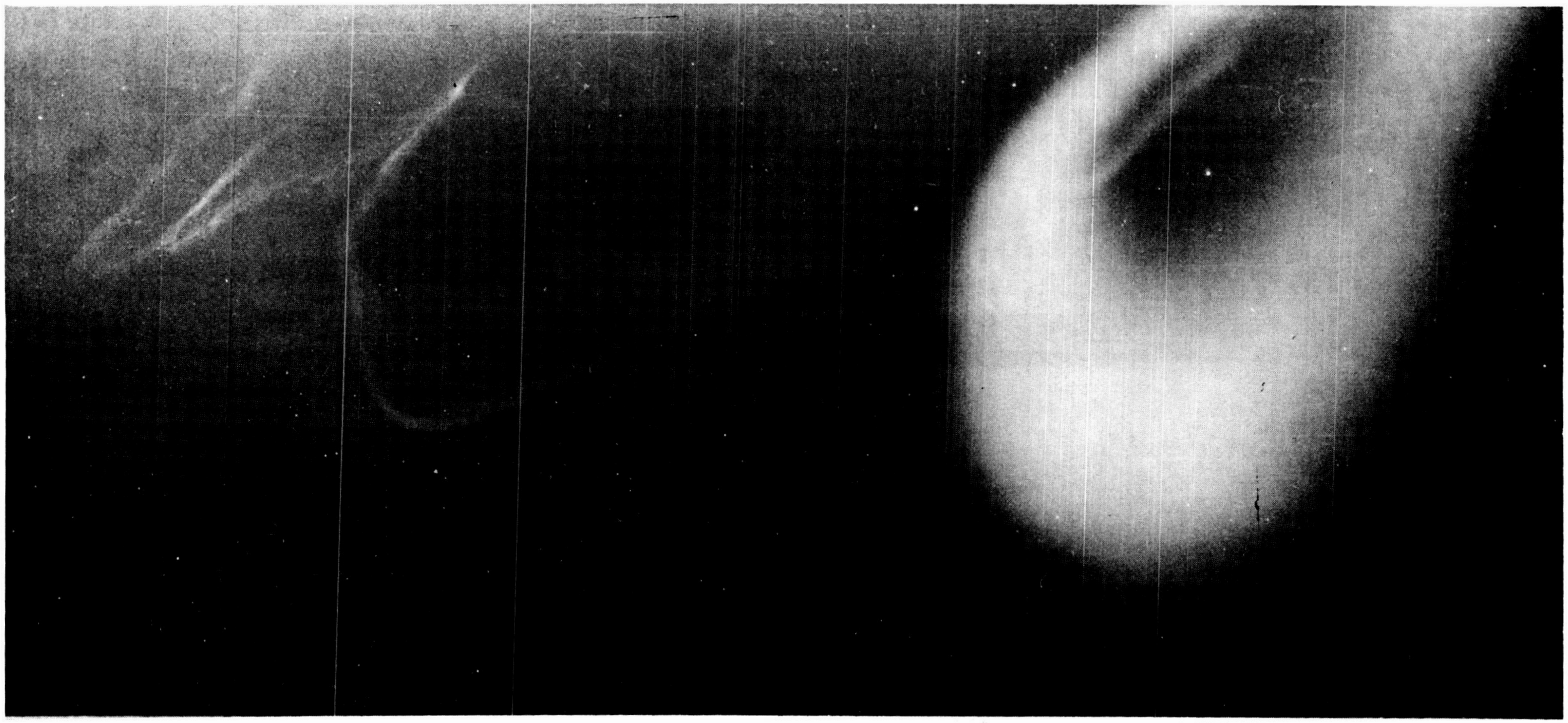

Figure 7.--Trimethylene aluminum shot of 3 November 1964 photographed at 04:42:08.

Figure 8.--Trimethylene aluminum shot of 3 November 1964 photographed at 04:47:57.

Table 1.--Chamical sodium shoot photography from Villa Dolores.
Evening 5 November 1964 - Launch time 23:16:00 Z (20:16:00 Local)

Time	B-N Frames*	Log Remarks by Station Personnel
From 23:17:42 To 23:17:58	5 frames 8 sec cycle	Rocket spotted. Photography started. Only a small portion of trail on film.
		Camera was moved to locate cloud on field of view better.
From 23:18:02 To 23:19:09	17 frames 8 sec cycle	Shows rocket ascending and nice contortions beginning to form in trail. Quality good.
		Rocket moves off film. Here camera was moved slightly to center turbulent region.
From 23:19:17 To 23:20:17	16 frames 8 sec cycle	Nice trail contortions. Quality good.
		Camera moved to center interesting region.
From 23:20:25 To 23:21:21	15 frames 8 sec cycle	Trail contortions expanding. Here interesting region is beginning to exceed five degrees width of camera field.
23:21:25		Frame ruined because film had to be cut to process.
From 23:21:29 To 23:22:21	14 frames 8 sec cycle	Same region. Still good.
		Camera moved here to descending cloud trail in effort to get beginning of convolutions.
From 23:22:49 To 23:23:21	9 frames 8 sec cycle	Photos of "descending" column.
23:23:30	1 frame 32 sec cycle	This was tried to see if image quality would be better. (good, but too dark-16 sec cycle would have been ideal).

Table 1 (Cont.)

Time	B-N Frames*	Log Remarks by Station Personnel
From 23:23:39 To 23:24:35	8 frames 16 sec cycle	Good quality, however not too much turbulence evident. "Ascending" column getting fainter.
		Here camera was positioned with field horizontal instead of vertical in effort to get both turbulent regions on field.
From 23:25:57 To 23: 6:13	3 frames 16 sec cycle	Ok
From 23:26:21	1 frame	Here shutter stopped and momentarily left open as rate changed to 32 sec cycle. Beginning to get darker.
From 23:26:42 To 23:27:46	5 frames 32 sec cycle	Seeing is getting poorer.
From 23:28:05 To 23:28:37	5 frames 16 sec cycle	Quality here not so good.
		Here oriented camera long field vertically again, to try to get better coverage of ascending part, which was much better looking, (more contrast to naked eye), than downfall section, which was almost faded out.
From 23:29:30	51 frames 16 sec cycle	Photos δδ ascending portion. First few frames ok, but quality degenerates as sky gets very dark and stratus clouds begin to move in and merge with rocket trail.

Here follow eight frames, four with f/4 diaphragm and filter, varying cycle rates, and four with f/1 opening (no diaphragm) and no filter, varying cycle rates. Nothing is distinguishable except sodium cloud merged with stratus. This was taken as a check.

Morning 6 November 1964 - Launch time 08:32:00 Z (05:32:00 Local)
(Same filter, same diaphragm)

Time	B-N Frames*	Log Remarks by Station Personnel
From 08:33:30 To 08:34:00		Looked for rocket in same place at corresponding time as previous night. Saw nothing.

Table 1 (Cont.)

Time	B-N Frames*	Log Remarks by Station Personnel
		Rocket spotted: much higher than before.
From 08:34:32 To 08:34:48	3 frames 16 sec cycle	No nice clean trail, only a "blob" visible.
From 08:35:04 To 08:37:36	20 frames 16 sec cycle	Moved camera to center "blob". Disappointing.
From 08:38:12 To 08:38:20	2 frames 16 sec cycle	Different portion δδ "blob" in attempt to get fall portion.
		Moved camera slightly.
From 08:38:29 To 08:39:01	5 frames 16 sec cycle	Here descending trail beginning to form. Ok, but poor cloud.
		Here relocated camera slightly to get a "V" that is beginning to form.
From 08:39:17 To 08:40:52	13 frames 16 sec cycle	Nice, but can't get all of the "V" on field. One frame chopped in two to process. Maybe 32 sec cycle would have been better.
		Here relocated camera horizontally to get two "V's", one up-side, the other on the down-side.
From 08:41:49 To 08:43:01	10 frames 16 sec cycle	Both "V's" covered. Best of all morning shot photos. Almost fills up field of camera. Don't know how up-rising "V's" formed as was nothing there previously.
		Here changed to eight sec cycle. Think sky was too bright.
From 08:43:11 To 08:45:35	37 frames 8 sec cycle	Here "V's" expanded greatly but there is very little definition in sky or on film. General outline is all.
From 08:45:58 To 08:47:14	20 frames 8 sec cycle	Here moved camera to keep "V's" on field. Shame there is no more contrast: interesting formation.

Table 1 (Cont.)

Time		B-N Frames*	Log Remarks by Station Personnel
From To	08:47:59 08:48:55	15 frames 8 sec cycle	Chasing expanding "V" on downfall side. Sky getting brighter. Tried to get vertical alignment to show twists lower on down falling side.
From To	08:50:16 08:50:52	19 frames 4 sec cycle	Getting very bright. Interesting twisty tail but very low contrast. Hardly visible due brightness. Here cloud fades out.

*Baker Nunn nomenclature -

4 sec cycle rate:	0.4 sec exp every	2 secs.
8 sec cycle rate	0.8 sec exp every	4 secs.
16 sec cycle rate	1.6 sec exp every	8 secs.
32 sec cycle rate	3.2 sec exp every	16 secs.

f/4 diaphragm has four holes each $2\frac{1}{2}$ inches in diameter.
f/1 is regular 20-inch diameter lens.

Table 2.--Trimethylene aluminum field results - 3 November 1964.

Time in min. after sunset	Cycle rate	Diaphragm	Filter	Magnitude faintest star	Background fogging
start to 82	16	f/8.0	A-23	1-2	none
82 to 88	16	f/4.0	A-23	***	***
88 to 98	08	none	none	6-10	slight
98 to end	16	none	none	10-15	none

***These settings were not used, but examination of the film exposed during this period indicates that this set would have produced good results.

Table 3.--Trimethylene aluminum shot photography
SC12-15804 (1 November 1964)

Time		B-N Frames*	2/Cycle	Log Remarks by Station Personnel
From To	06:21:58 06:23:10	10	16	Photography started (at 22:14, Figure 4). Reentering rocket? Cloud on all frames.
				Altitude change.
From To	06:23:35 06:24:40	8	16	Cloud on all frames (extreme right end of film).
From To	06:25:54 06:26:26	4	16	Some useless frames (altitude change). Portion of cloud trail in center.
				Change in altitude.
From	06:26:54			Figure 5 cloud in center of frame. Good quality
				Trail contortions expanding, Figure 4. Main portion covering three degrees wide field.
To	06:40:50	105	16	Figure 6 at 39:46. Good photography on all frames some sky area-star field stationary camera.*
From To	06:40:59 06:41:07	5	4	Poor (faint) inadequate exposure (experimental).
				*Main section of cloud expanded to approximate by an eight degrees sky area. Appears similar to an edge on galaxy (Andromeda minus its dense nucleus).
SC12-15805 (3 November 1964)				
From To	06:36:19 06:41:39	41	16	Red filter used. Only a dozen photos show release.

Table 3 (Cont.)

Time	B-N Frames	2/Cycle	Log Remarks by Station Personnel
From 06:42:04 To 06:42:40	10	8	No filter. Matter (poor). Good. See Figure 7 at 42:08. Portion of cloud distorted forming loop-like arrangement. Some background fog.
From 06:46:28 To 06:48:32	32	8	Azimuth change.
			Loop expanding.
			Less background fog.
From 06:50:13 To 06:51:21	17	8	Most of cloud in field of view.
			Cloud diffusing some frames have been affected by light leaks.

BAKER-NUNN TRACKING OF THE AIR DENSITY EXPLORER BALLOON AND THE INJUN EXPLORER SPACECRAFT[1]

by

Ellis A. Monash[2]

Abstract.--The Smithsonian Astrophysical Observatory was requested to track the Air Density Explorer balloon and the Injun Explorer spacecraft by the National Aeronautics and Space Administration. The inflation of the Air Density Explorer balloon and the separation of the Injun Explorer spacecraft were confirmed by the Smithsonian Astrophysical Observatory, South Africa Station.

The Smithsonian Astrophysical Observatory received nominal orbital elements on November 14, 1964, from Goddard Space Flight Center for the Air Density Explorer. From the orbital elements, two ephemerides were computed and distributed to the twelve Baker-Nunn stations via teletype. In addition, instructions were included to confirm the separation of the Air Density Explorer balloon and the Injun Explorer spacecraft from the rocket hardware, the inflation of the balloon, the number of objects placed into orbit, the apparent brightness of each piece in orbit, and an identification and position of each piece.

After the launch on November 21, 1964 at $17^h09^m.65$ UT, a complete description of the various pieces in orbit was issued from the Smithsonian Astrophysical Observatory, South Africa Station (Station 02). They initially confirm five pieces placed into orbit at the position and time indicated by the predictions. They listed their observations of the various pieces in order of their relative positions observed in the sky.

The first piece observed appeared at $18^h09^m32^s$ UT, leading the balloon by about 8.5 minutes of arc. The object flashed at a brightness of magnitude 8 with a frequency of about 0.6 sec^{-1}. This piece is the furthest from the balloon (Figure 1) and is labeled piece A. (See Figure 4.)

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[1]Supported by grant number NsG 87/60 from the National Aeronautics and Space Administration.

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Piece B possessed characteristics similar to those of A. It too showed flashing, but it was brighter than piece A by one magnitude. At $18^h15^m.4$ UT, the image of piece B on the Baker-Nunn film showed two distinct parallel trails separated by about 10 seconds of arc (Figure 2). In the plot of the relative separation of the various pieces from the balloon (Figure 1), the slope of piece B displayed a break, indicating that the Injun Explorer spacecraft separated from its housing unit. When the Injun Explorer space craft became a single entity, a Cospar number, 6407602, was assigned to it. (See Table 2 for Orbital Elements.)

The third piece, C, observed on the Baker-Nunn film is the brightest at magnitude 5. We feel that it is the balloon since it is the brightest in the group. Initially, we felt that the apparent brightness when first observed would lie in the range from third to sixth magnitude; therefore, we conclude the balloon is fully inflated as planned. The Air Density Explorer balloon is also assigned a Cospar number, 6407601. (See Table 2 for Orbital Elements.)

Piece D, the fourth piece, is considerably fainter than the balloon at an apparent brightness of magnitude 8. It also flashes as do pieces A and B, trailing the balloon by the least separation of all the pieces.

The fifth piece, Piece E, is difficult to distinguish from piece D, since it is fainter by at least one magnitude and very close to piece D on the film.

Another confirmation (Figure 3) of the various Air Density Explorer pieces shows the direct separation of four pieces for several days at Smithsonian Astrophysical Observatory Australia Station.

At present, we hope to track the Air Density Explorer for its entire life learning as much as possible from the interaction of the balloon and its environment.

Acknowledgments

I would like to thank Mrs. Beatrice Miller and Mr. Bob Martin for reading the manuscript and making suggestions for its improvement.

References

NASA Press Release, Release Number 64-284, 13 November 1964 (This report describes the scientific objectives of Air Density Explorer and Injun Explorer, the construction and characteristics of the satellites, including a description of the launch vehicle).

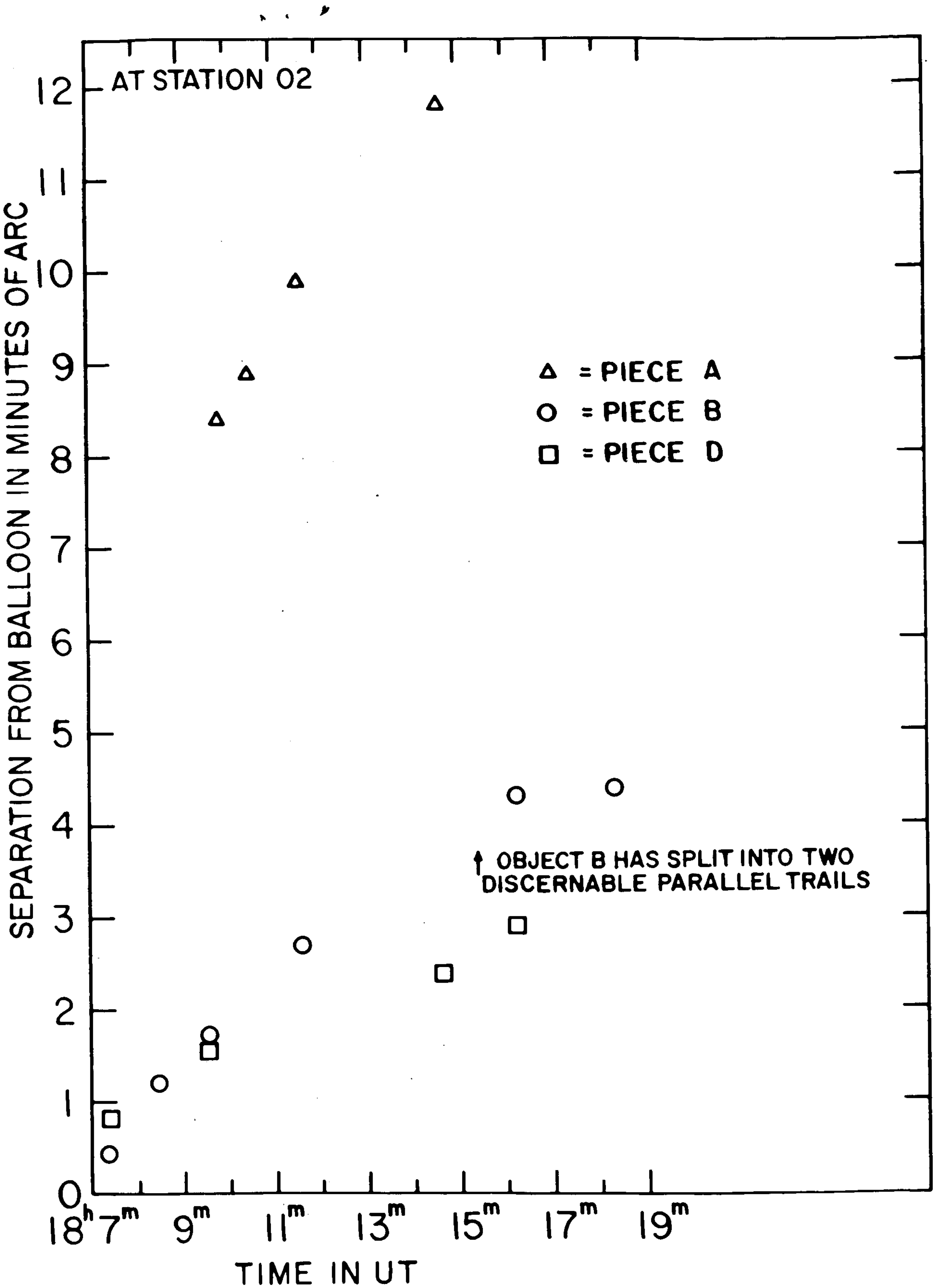

Figure 1.--Separation of pieces A, B, and D from piece C (Air Density Balloon) on 21 November 1964.

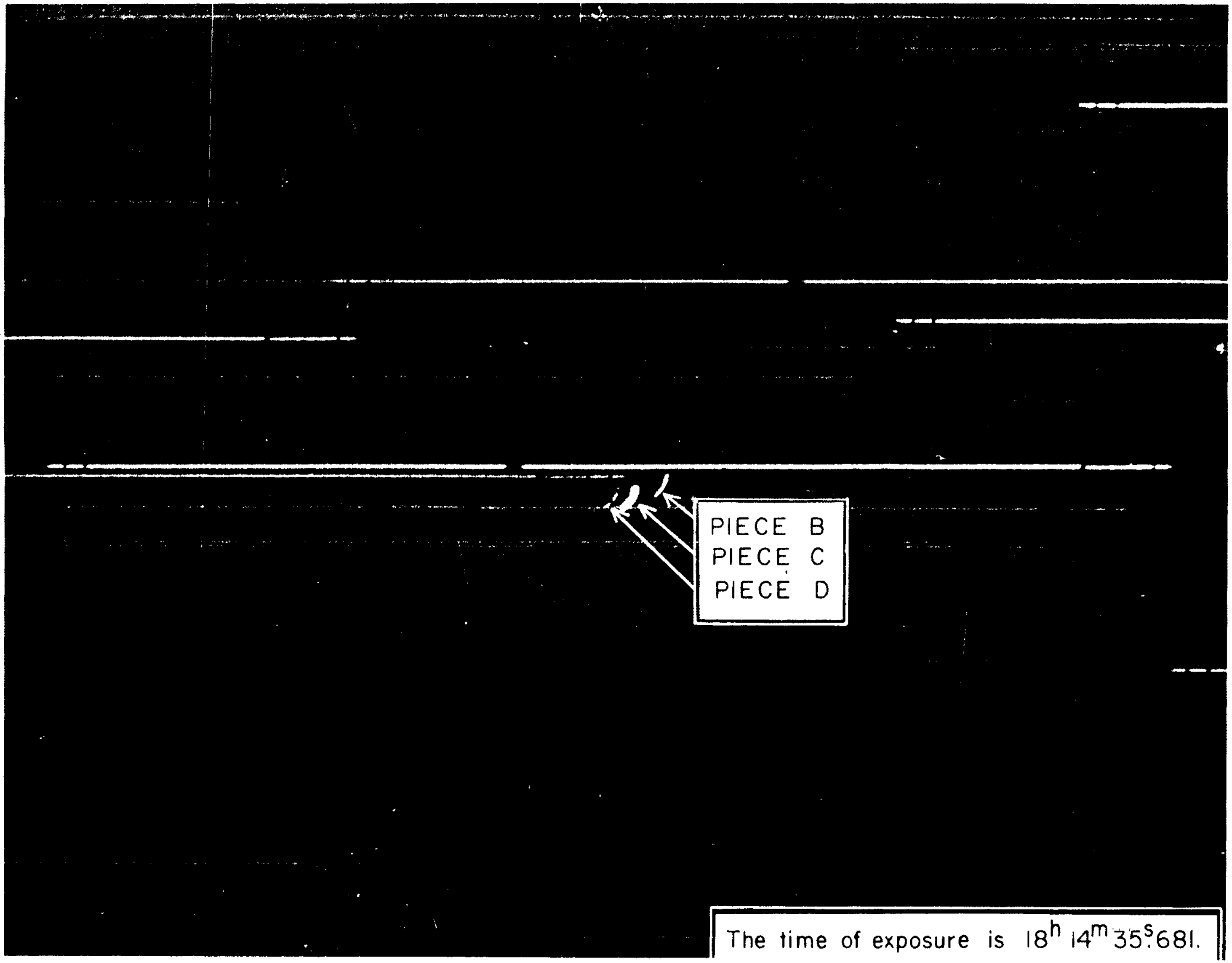

Figure 2.--Baker-Nunn photographs of Air Density Explorer Balloon and Injun Explorer spacecraft showing
(a) the separation of Injun Explorer spacecraft from its housing.

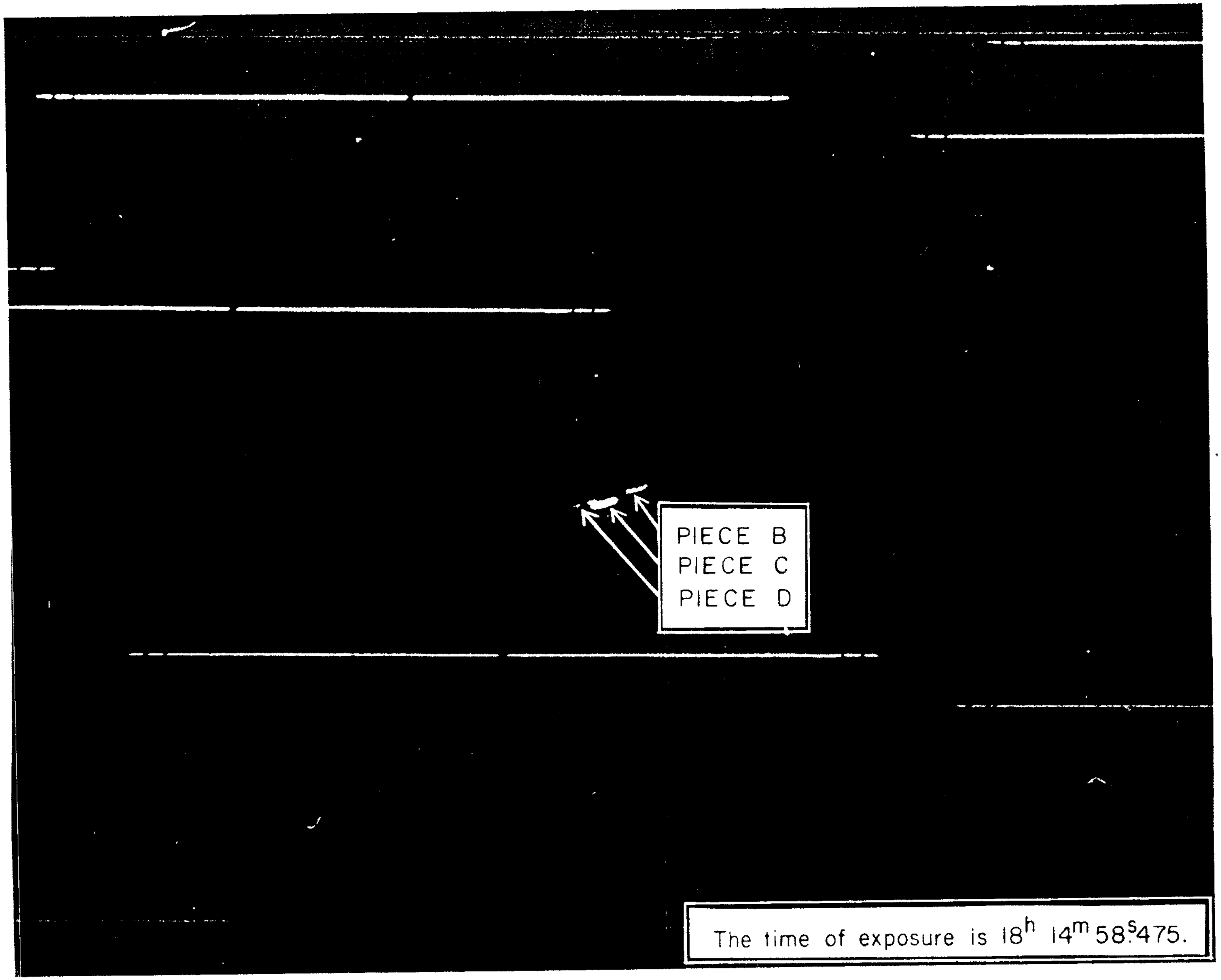

Figure 2
(b)

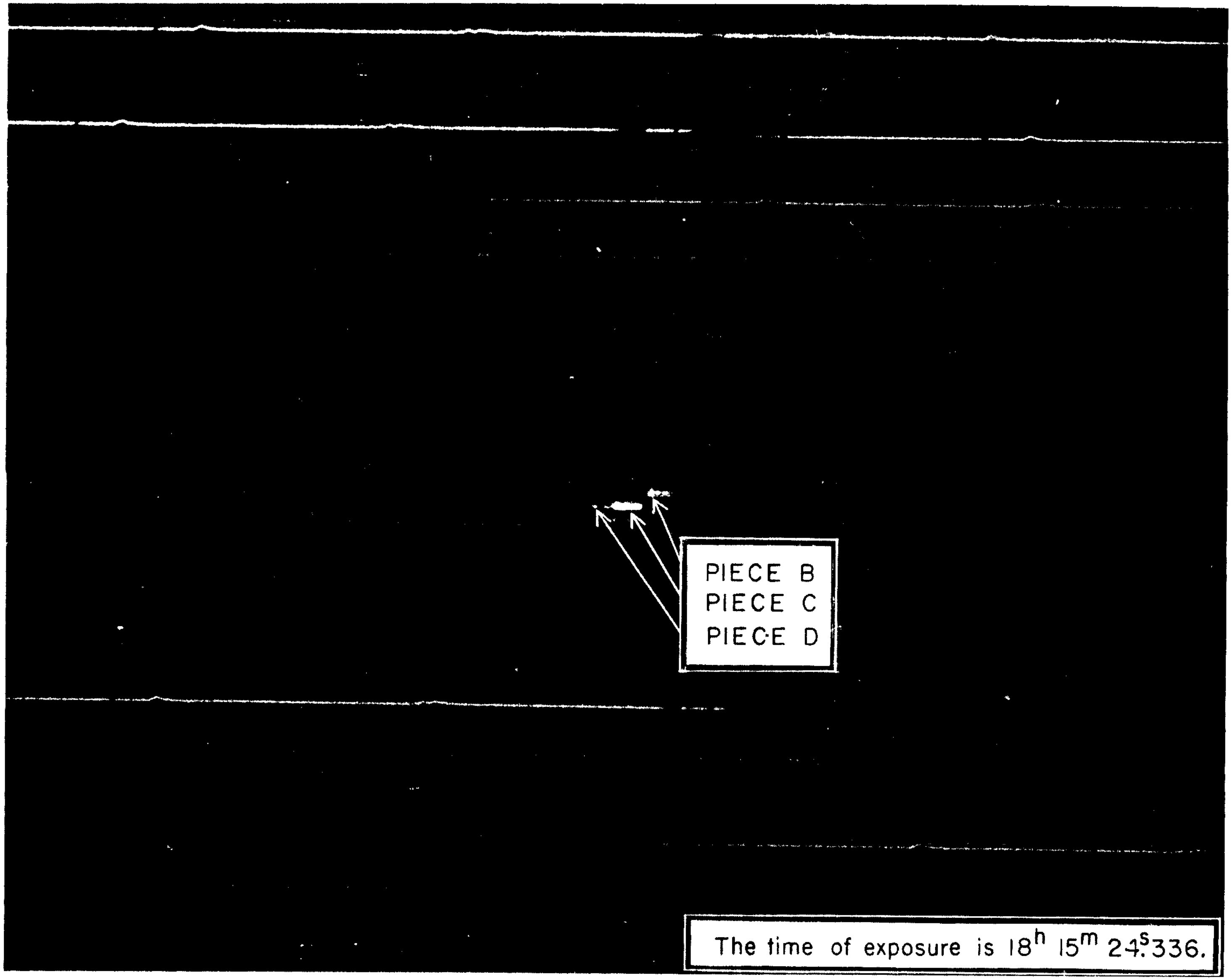

Figure 2
(c)

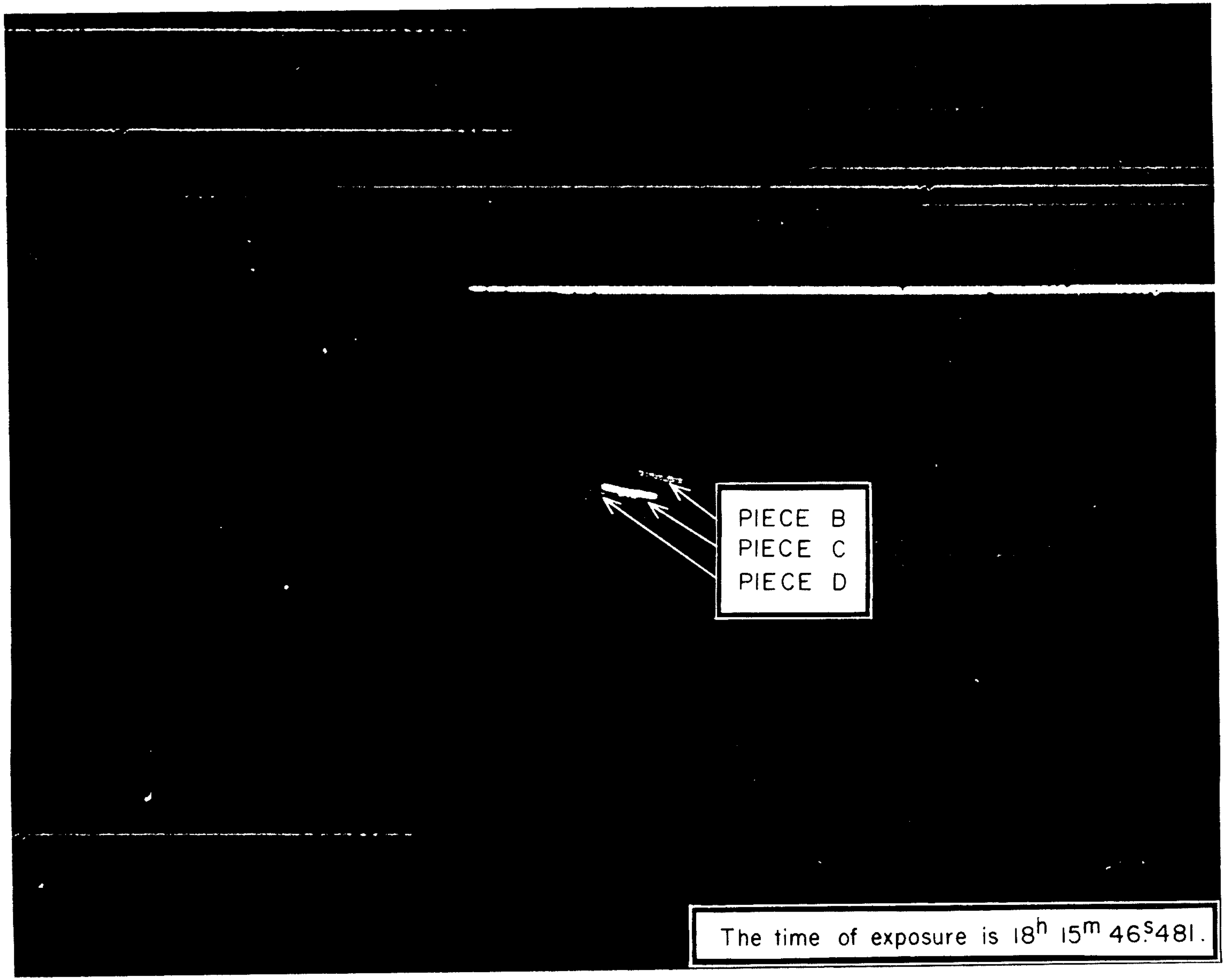

Figure 2
(d)

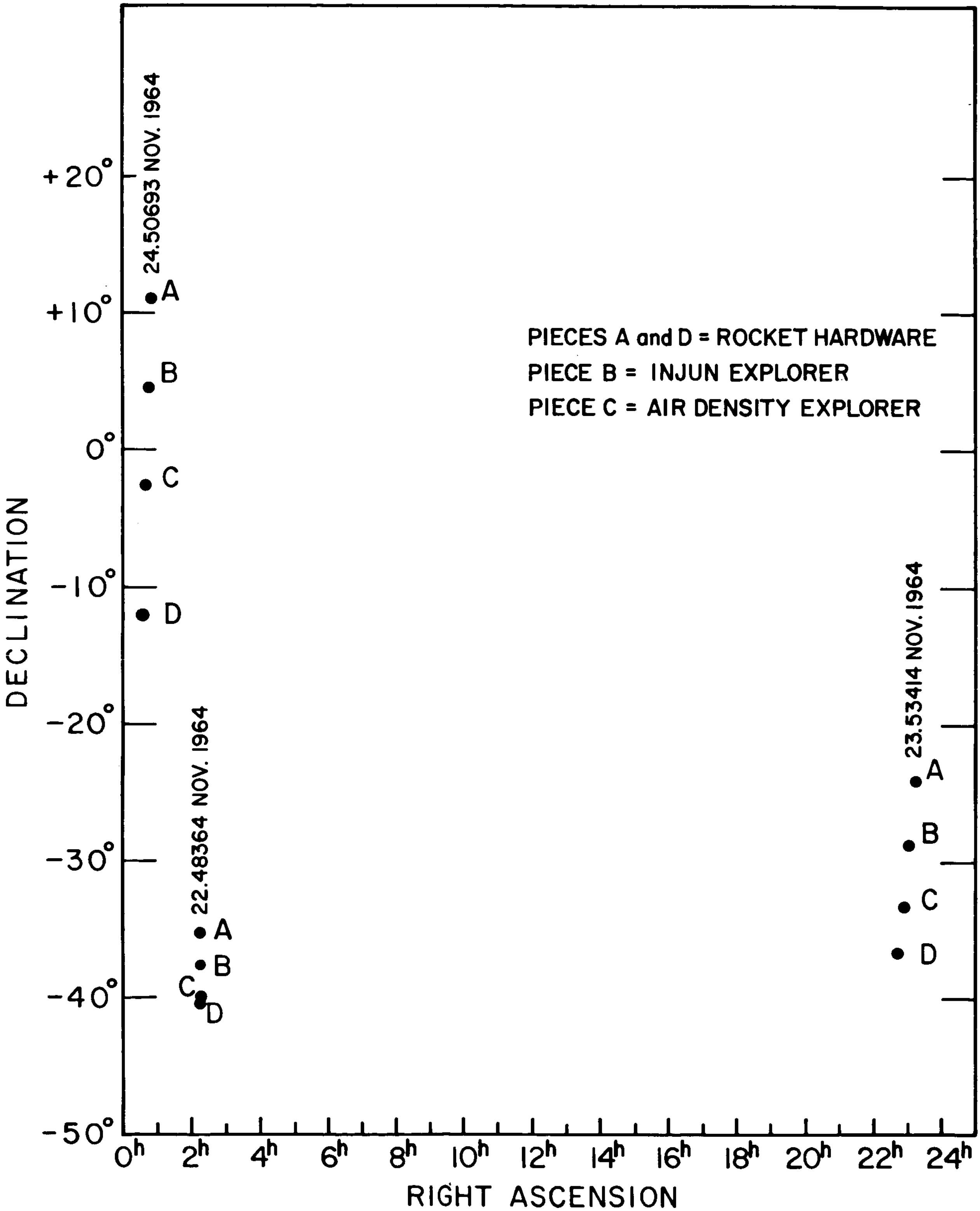

Figure 3.--Separation of the various components of the air density explorer from day to day at station 23.

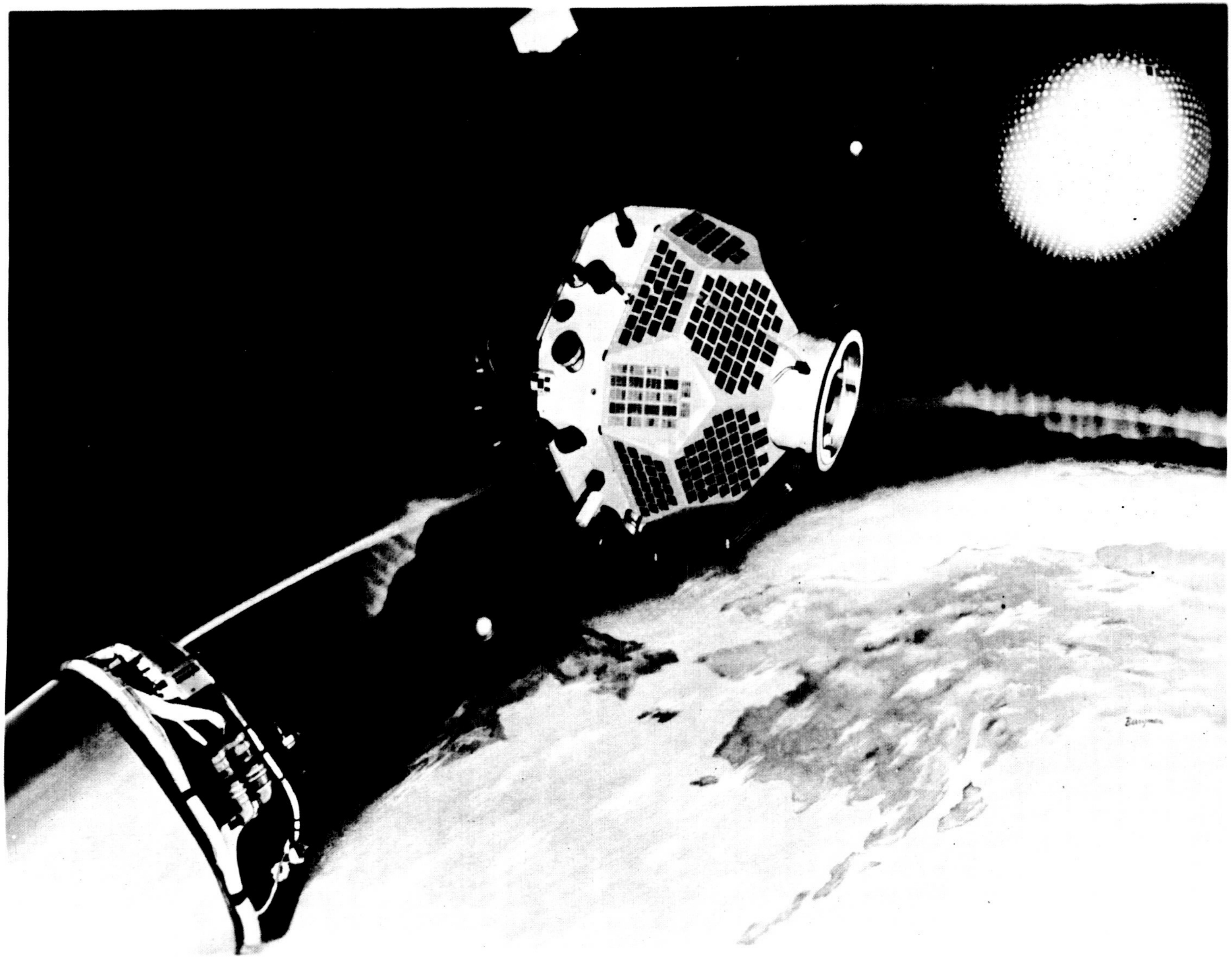

Figure 4.--Artist's conception of Air Density Explorer (upper right) and Injun Explorer Spacecraft (center) orbiting the earth. The leading piece (lower left) is the rocket casing.

Table 1

Physical Characteristics of Air Density Explorer and Injun Explorer

Satellite	Diameter	Mass	Satellite Material	Average Satellite Density	Satellite Area-to-Mass Ratio
Air Density Explorer	366 cm	8.6 kgm	Aluminum-Mylar	$3.35(10)^{-4}$ gm cm^{-3}	12.2 $cm^2 gm^{-1}$
Injun Explorer	61 cm	40 kgm	-	$3.36(10)^{-1}$ gm cm^{-3}	$7.3(10)^{-2} cm^2 gm^{-1}$

Table 2

Orbital Elements of 6407601 and 6407602

Satellite 1964 76 A (6407601)

I. SAO elements

The following elements are based on 80 observations and are valid for the period November 21 through December 2, 1964.

$$T_0 = 38726.0 \text{ MJD}$$

$$\omega = (155\overset{\circ}{.}020 \pm 94) - (2\overset{\circ}{.}174 \pm 28)t$$

$$\Omega = (20\overset{\circ}{.}5833 \pm 50) - (0\overset{\circ}{.}73128 \pm 97)t$$

$$i = (81\overset{\circ}{.}3610 \pm 98)$$

$$e = (.124978 \pm 82)$$

$$M = (.36377 \pm 33) + (12.384588 \pm 99)t + (.6162 \pm 90) \times 10^{-4}t^2 - (.214 \pm 30) \times 10^{-5}t^3$$

Standard error of one observation: $\sigma = \pm 3\overset{\prime\prime}{.}02$.

Satellite 1964 76 B (6407602)

I. SAO elements

The following elements are based on 45 observations and are valid for the period November 21, 1964 through December 2, 1964.

$$T_0 = 38726.0 \text{ MJD}$$

$$\omega = (155\overset{\circ}{.}163 \pm 69) - (2\overset{\circ}{.}191 \pm 18)t$$

$$\Omega = (20\overset{\circ}{.}5722 \pm 32) - (0\overset{\circ}{.}73335 \pm 41)t$$

$$i = (81\overset{\circ}{.}3619 \pm 58)$$

$$e = (.125114 \pm 52)$$

$$M = (.39633 \pm 25) + (12.390565 \pm 64)t + (.65 \pm 45) \times 10^{-6}t^2$$

Standard error of one observation: $\sigma = \pm 1\overset{\prime\prime}{.}20$

OBS NO	STATION	STA NO	DATE	TIME	R. A.	DECL.	AZIMUTH	ALTITUDE	RANGE	INDEX
10003	OLIFANTS	9002	64 11 21	19 04 26.76	5 48 18	-64 59				434023
10004	OLIFANTS	9002	64 11 21	18 08 00.92	4 21 48	-48 21				434023
10005	OLIFANTS	9002	64 11 21	18 10 10.92	3 56 18	-35 20				434023
10006	OLIFANTS	9002	64 11 21	18 18 14.17	3 24 54	12 33				434013
10008	LAGOON	9023	64 11 22	11 36 26.72	2 13 30	-40 03				434023
10009	LAGOON	9023	64 11 22	11 43 16.51	2 09 12	10 45				434013
10014	LAGOON	9023	64 11 23	10 50 58.72	3 41 24	-45 03				434023
10015	LAGOON	9023	64 11 23	10 59 52.32	2 57 54	11 19				434013
10016	LAGOON	9023	64 11 23	12 49 09.46	22 53 30	-33 17				434023
10017	LAGOON	9023	64 11 23	12 52 39.16	23 31 42	- 9 39				434013
10018	OLIFANTS	9002	64 11 23	18 41 32.74	2 24 12	-24 00				434023
10023	V. D.	9011	64 11 24	0 25 00.98	3 24 00	-49 39				434023
10024	V. D.	9011	64 11 24	0 25 35.02	3 17 06	-45 38				434023
10025	V. D.	9011	64 11 24	0 25 51.02	3 14 12	-43 47				434023
10026	LAGOON	9023	64 11 24	12 10 06.65	0 40 36	- 1 40				434013
10026	LAGOON	9023	64 11 24	14 05 10.34	22 24 42	- 6 39				434013
10019	OLIFANTS	9002	64 11 24	17 53 44.88	3 53 06	-45 19				434023
10020	OLIFANTS	9002	64 11 24	19 53 22.92	23 11 54	-26 56				434023
10021	OLIFANTS	9002	64 11 24	19 54 59.18	23 25 06	-16 41				434013
10022	OLIFANTS	9002	64 11 24	19 56 50.19	23 39 30	- 2 51				434013
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10046	LAGOON	9023	64 11 25	11 22 01.59	1 49 00	-35 09				434023
10047	LAGOON	9023	64 11 25	11 24 19.66	1 48 18	-16 16				434013
10048	LAGOON	9023	64 11 25	13 20 31.70	22 33 54	-12 23				434013
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OBS NO	STATION	STA NO	DATE	TIME	R. A.	DECL.	AZIMUTH	ALTITUDE	RANGE	INDEX
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10027	AREQUIPA	9007	64 11 29	0 42 03.71	2 32 24	-20 11				434013
10028	AREQUIPA	9007	64 11 29	0 42 43.71	2 32 00	-15 02				434013
10038	OLIFANTS	9002	64 11 29	18 04 26.30	1 56 12	-32 56				434023
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10047	AREQUIPA	9007	64 12 01	1 10 07.04	0 48 54	-15 31				434013
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10045	JOHNSTON	9117	64 12 01	7 07 44.01	2 46 42	-19 23				434013
10046	JOHNSTON	9117	64 12 01	7 08 00.01	2 47 54	-17 34				434013
10056	LAGOON	9023	64 12 01	10 45 08.34	1 21 42	-31 59				434023
10057	LAGOON	9023	64 12 01	10 47 46.44	1 23 48	-10 30				434013
10058	LAGOON	9023	64 12 01	12 40 22.51	21 45 18	-26 15				434023
10059	AREQUIPA	9007	64 12 02	0 24 49.52	2 18 12	-20 12				434013
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10062	CURACAO	9009	64 12 02	0 33 53.94	2 19 48	-14 18				434013
10063	CURACAO	9009	64 12 02	2 30 05.78	22 24 36	-10 42				434013
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