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The Corralitos Observatory Program for the Detection Of Lunar Transient Phenomena

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16. Abstract

This is a final report on the establishment, observing procedures, and observational results of a survey program, carried out at the Corralitos Observatory of Northwestern University, for the detection of lunar transient phenomena (LTP's) by electro-optical image conversion means in accordance with NASA grant NsG-497. For survey, a unique detection system with an image orthicon was used as the primary element in conjunction with a 24-in. *f*/20 Cassegrainian telescope. Observations in three spectral ranges, with 6466 man-hours of observing, were actually performed during the period from October 27, 1965, to April 26, 1972. Within this entire period, no color or feature change within the detection capabilities of the instrumentation was observed, either independently or in follow up of amateur LTP reports, with the exception of one general bluing and several localized bluings (probably ascribable to the effects of the terrestrial atmosphere) that were observed solely by the Corralitos system. A table is presented indicating amateur and professional reports of LTP's and the results of efforts to confirm these reports through the Corralitos system.

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THE CORRALITOS OBSERVATORY PROGRAM FOR THE DETECTION OF LUNAR TRANSIENT PHENOMENA

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INTRODUCTION

Lunar transient phenomena (LTP's) have been reported since 1540, and reports have been particularly numerous in the mid-20th century. Interest in the suspected lunar transient events was heightened by the proposed NASA lunar 'anding program; definitive confirmation and a scientific study of these reported changes became necessary in the pursuit of the Apollo program. There were numerous suggestions on how an active watch for LTP's might be conducted. For instance, it was suggested that the Smithsonian Moonwatch program, which involved several hundred volunteer teams, be employed in watching for lunar phenomena. However, it became clear that interest among amateur groups would be very likely to lag if LTP's did not appear with some frequency. The rewards in the ongoing Moonwatch program had been that practically every evening the observers saw a satellite and made significant observations.

There were additional reasons to pursue a program of search for LTP's. Quoting from the President's message to Congress of January 27, 1965,

> The program was initiated to develop instruments to detect extraterrestrial resources indicated by transient events on the lunar surface. The objective is the automatic detection and analysis of lunar phenomena such as red colored spots which were sighted in 1963. Scientific analysis of such phenomena may indicate energy sources on the lunar surface which may be exploited.

Thus, both from the standpoint of the conduct of the Apollo program and the possibility of new natural resources, it seemed wise to conduct an LTP program.

It was early realized, largely through discussions between Dr. Urner Liddel, Dr. J. Allen Hynek, and several colleagues, that an amateur approach to this problem, for instance using organized groups of amateur astronomers, would not be adequate. Consequently, in December 1963, a professional, NASA-supported program for LTP observations was proposed.

A specific proposal for a professional program for surveillance of the lunar surface in search of LTP's was submitted to NASA in January 1964 with Dr. Hynek as principal investigator. It was planned to use image conversion techniques employing image orthicons that had been developed at Northwestern University's observatory in New Mexico and successfully applied there to several astronomical problems—particularly those requiring observations of short, real-time variations. Accordingly NASA grant NsG-497 was awarded (in July, retroactive to June 1, 1964) to initiate the surveillance program.

It was originally planned to locate the telescope at Organ Mountain Station, N. Mex., where Northwestern's observatory was located. However, inability to acquire the necessary additional land, coupled with increasingly adverse observing conditions, such as lights at the White Sands Missile Range nearby, led to the search for a more suitable site. The site chosen was on Federal land in the Corralitos Ranch, near the intersection of the Sleeping Lady Hills and the Rough and Ready Hills, approximately 21 road miles from Las Cruces, N. Mex. initial tests of the sky darkness, wind velocity, weather conditions, and quality of stellar seeing disks indicated that the Corralitos site was superior in each respect to the Organ Mountain Station site, not only for this new program but for other astronomical applications.

The primary instrument used in the lunar program was a 24-in. *f*/20 Cassegrainian telescope, constructed originally by Ferson Optics, Inc. The choice of this diameter for t'.e telescope represented an optimization of three factors: optical resolution, light-gathering power, and the effects of atmospheric distortion. With a 24-in. telescope, it is possible to gather enough light to permit a matching of the orthicon resolution to the theoretical resolution of the system by using enlarging projection optics. Also, integration times of as short as 1/100th of a second and shorter may be used on bright objects. The instrument was housed in a 16- by 20-ft cement block building which supported a 16 ft Ash Dome. (See figs. 1 and 2.)

The image orthicon system was designed and built at the Dearborn Observatory, under the primary direction of W. T. Powers, after the technical staff found that no suitable commercially available image orthicon system was acceptable and that commercial development of such a television chain would greatly exceed the project budget. The final form of the image orthicon apparatus on the telescope and the main control board are shown in figures 3 and 4.

There were several reasons for using an image-orthicon-based detection system: first, image conversion incorporates one of the most important aspects of visual observations: the ability to utilize moments of best seeing; second, high resolution pictures of the Moon approaching the theoretical resolution of the optical system and rivaling those in the *Kuiper Lunar Atlas* can be obtained with such a system. Only a sensitive detector such as an image orthicon can combine very short integration times with high magnification to produce results that are not limited in resolution by factors of scanning pattern and in which the effects of even fairly bad seeing are minimized. Finally, a television system can be adjusted to act much as a photographic emulsion of arbitrary "gamma." Thereby, small differences in contrast can be accentuated and the detection of detail becomes nearly independent of lighting conditions (e.g., at full Moon), allowing features to be detected on the television monitor that would not be seen by a visual observer because of his limited ability to vary contrast.

The completely transistorized image orthicon camera, with its associated sweep output circuits and preamplifier, was mounted directly on the telescope. Heat-generating components, including the observer himself, were located in a lower control room, totally isolated from the telescope—an important consideration in optimizing resolution and astronomical seeing.

Because the observations of the television monitor were made visually to detect possible transient phenomena in real time, it was essential to minimize the effects of scan lines. This was accomplished by sequential scanning. The circuits were adjusted to provide a synchronization instability with the 680-line sequential scan, which gave a different number of lines on successive scans and was found to give superior definition. Laboratory and in-the-field testing proved that the overall stability of the system was quite exceptional. No two following scans had the same number of lines, although all were only a few lines different from the standard rate. One of the greatest problems of electronic scanning systems—the necessity for very frequent readjustments of the beam and dc level, target voltage, and dynode potentials to obtain optimum results—was largely eliminated.

The Corralitos Observatory was formally dedicated on October 12, 1965, and a program of continuing observation of the Moon, visually through color filters and by auxiliary photography, was begun October 27, 1965, under Justus R. Dunlap as the Chief Observer of the Corralitos Observatory. Although the building had been completed in January 1965, because of delays in funding the grant the Ferson Company sold the telescope that initially was scheduled for the project and had to build a new one. Some mechanical difficulties developed with this instrument because of the small size of the declination axle, causing considerable mechanical instability in the telescope. The axle was replaced with added logistic delays.

In the beginning a rotating color wheel was constructed by Dunlap utilizing three color filters (interference filters with dielectric coatings laminated between optical glass) with spectral transmission ranges of 3500 to 4600, 4600 to 6000, and 6000 to 8000 Å and several neutral density filters. The neutral density filters were used to compensate for the differences in sensitivity of the image orthicon cathode to the red and blue portions of the spectrum. This compensation was important, particularly when the variable atmospheric transmission as the Moon neared the horizon had to be taken into account. At such times, the red image intensity increased with respect to the blue and without compensation, a false color change would have been observed. The filter wheel has a 2-s cycle during which the red, visual, and blue filters were each in position successively for one-half-second periods. More rapid alternation of the

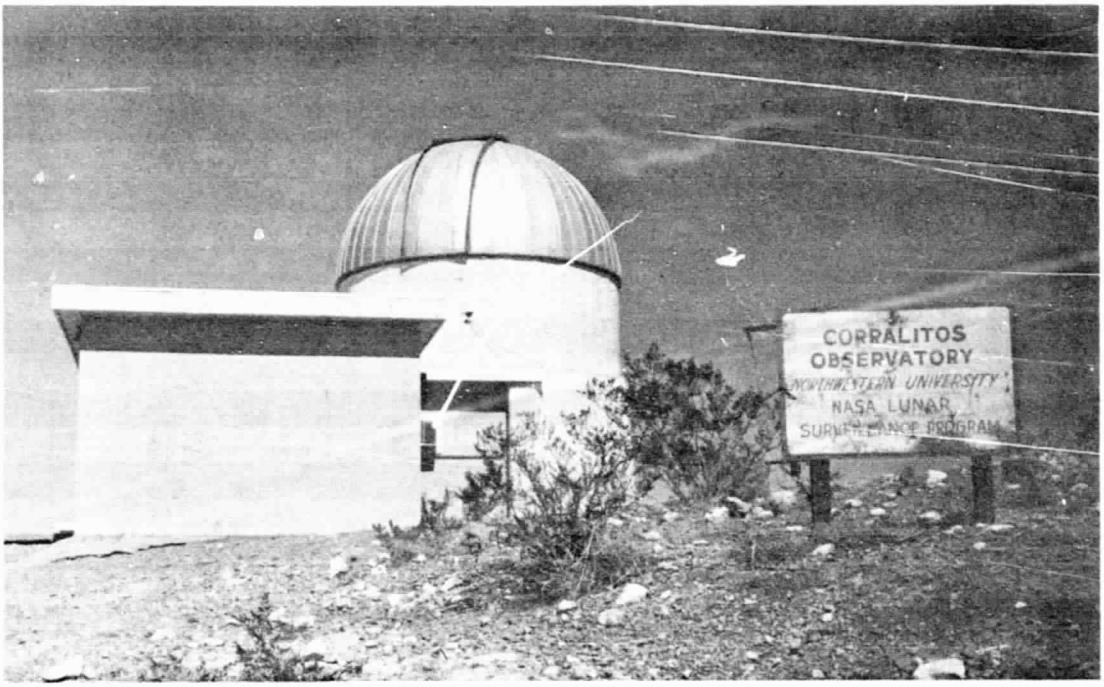

Figure 1.–Observatory building housing the Corralitos 24-in. telescope and orthicon system.

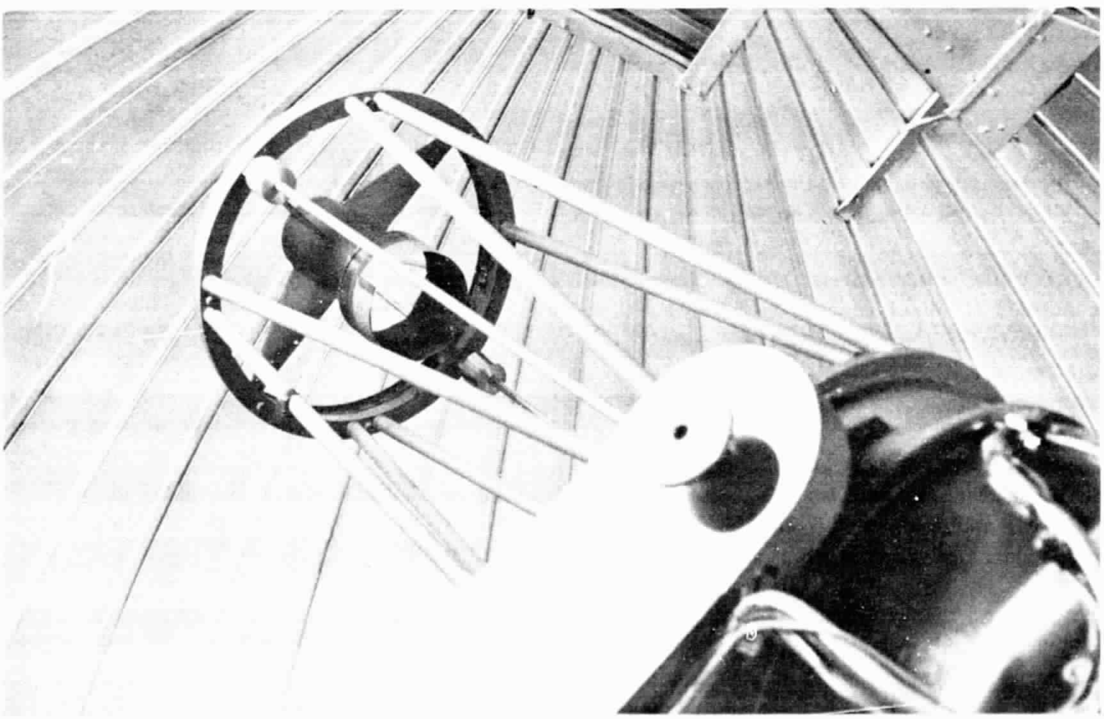

Figure 2.–The 24-in. telescope.

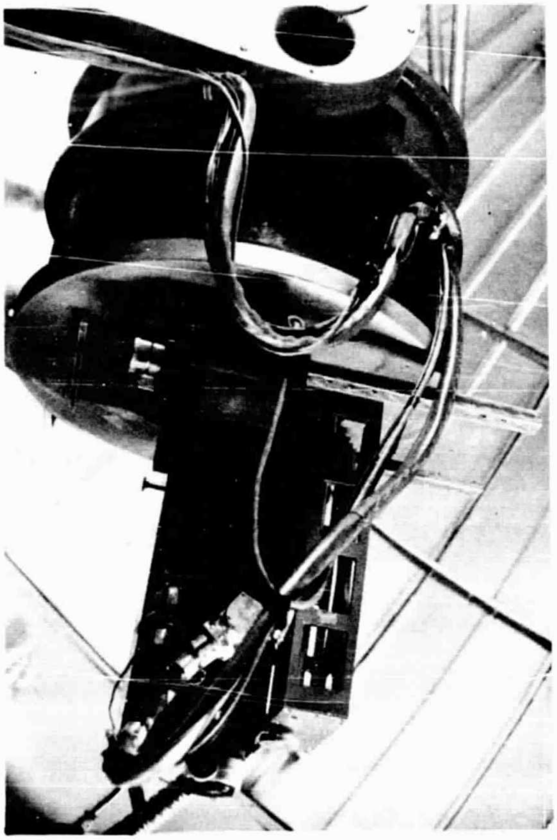

Figure 3.–The image orthicon camera and associated electronics in place on the telescope.

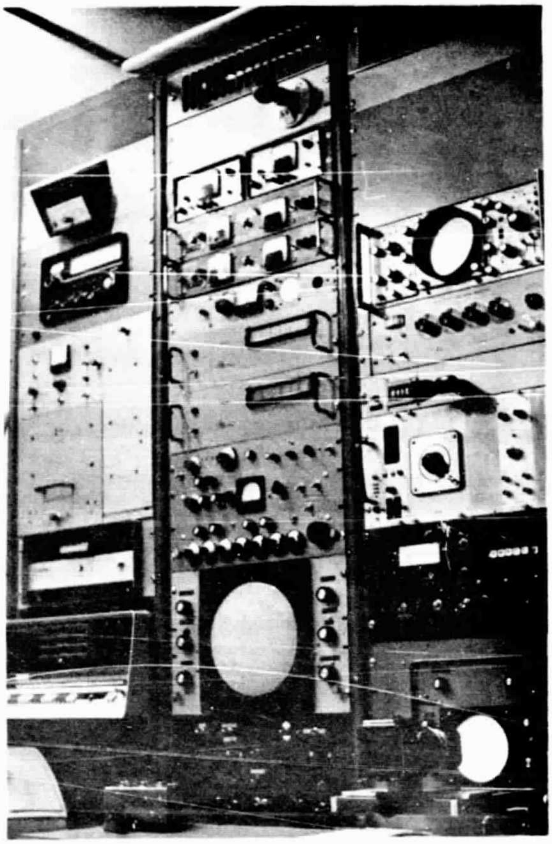

Figure 4.–The control panel of the 24-in. electro-optical system.

filters would not have allowed time for the image orthicon target to be erased between images.

From its initiation, the observational program was carried out by a team of four observers under the supervision of Justus Dunlap. The Moon was observed continuously during the hours of darkness, as it passed from 7° above the eastern horizon to 7° above the western horizon. Two observers, one a senior observer, remained on duty at all times, regardless of predicted weather. This allowed maximum use of semiclear as well as clear nights. Even mediocre skies with light uniform haze permitted lunar surveillance although a photometric progran. would have been inoperable. Observers spelled each other in periods of 20 min. The field of view of 6 by 6 arcmin was displayed on the monitor itself on a 9- by 9-in. screen. One line pair thus corresponded to slightly more than one-half second of arc. Seated approximately 2 to 3 ft in front of the monitor, the observer systematically scanned successive portions of the Moon, allowing several alternations of the red, visual, and blue filters for each feature. Although each observer surveyed the entire surface of the Moon, frequent attention was given to features that were considered most likely to show change, such as areas of Aristarchus and Alphonsus. The observer worked outward from a central feature in a "square spiral" to the perimeter of the field while using a reasonable amount of overlap. If a change was suspected, photographs were immediately taken of the monitor screen with one of the two cameras available, a 35-mm Praktica and a Hasselblad of larger format. Control photographs of the monitor screen were taken periodically for both record purposes and to keep the observers in practice should a lunar event occur. Representative photographs demonstrating the resolution attainable with the electro-optical system are shown in figures 5 and 6. A continuing observational log was also kept throughout the program.

Several image orthicon tubes with a variety of

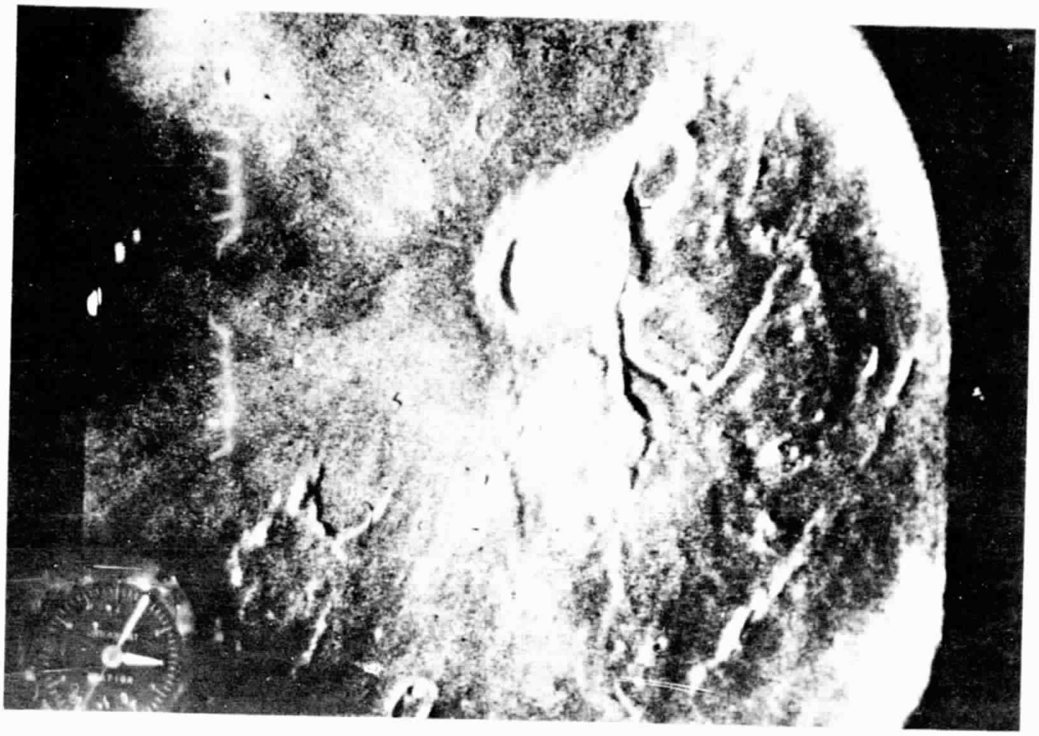

Figure 5.–Schröter's Valley as seen with the orthicon system.

Figure 6.–Copernicus as seen with the orthicon system.

photocathodes were available to the lunar surveillance program. An S-10 photocathode was used as the primary image orthicon tube for the 4 months of the year when unstable summertime atmospheric conditions would hamper more than two-color blinking. This photocathode was used because its spectral response extends 600 Å further into the near infrared than the human eye, the "instrument" generally used for reporting suspected LTP's. Although the sensitivity of the photocathode at these longer wavelengths is quite low, it was compensated by the gain inherent in the image orthicon system, which allowed useful information to be obtained at those wavelengths. Under the more stable atmospheric conditions of the rest of the year, the system employed an S-20 photocathode, which had a response of 3000 to 8500 Å. Only a minor imbalance of the three images occurred, and this was compensated for with the appropriate neutral density filters. Average seeing conditions permitted a practical resolution of 2 arcsec of the lunar surface, and occasional good seeing permitted resolution of 1 arcsec or even better.

When the Moon was not in view and weather conditions permitted, the telescope-orthicon system was fully programed for a supernova search. This research, which interfered in no way with the lunar surveillance program, will be referred to later in this report.

Interest in the detection of possible LTP's remained high among amateur astronomy groups and was, in fact, stimulated by the existence of a professional program. A rather interesting group of amateur astronomers who were also "radio hams" combined their two amateur interests by exchanging their reports of lunar observations in real time by radio. This relatively large group, called the Argus Astro-Net, made generally sporadic observations that were concentrated at the crescent and first quarter phases when the Moon was available for early evening observations. Their observations were carefully monitored, using a Drake 2B shortwave receiver. Starting in February 1966, the Corralitos observing staff regularly monitored the Argus Astro-Net and many of the conversations were taped. A large number of events that were reported were immediately checked by the Corralitos staff. The results of attempted confirmations of these and other events appear in table 2 (in the next section of this report).

To better monitor the changes reported by amateur groups, the Corralitos staff undertook a regular program of infrared observations of the lunar surface, concurrent with the primary three color monitoring, in January 1966. This appeared to be a very promising method of detecting highly localized thermal changes on the Moon that might not have corresponding visual changes. A second television camera was constructed with an S-1 photocathode and a spectral response of 300 to 10 800 Å. All wavelengths shorter than 8000 Å were removed from this system by the means of an interference filter. This image orthicon and a separate optical system of 5-in. aperture were both mounted on the tube of the 24-in. telescope. The infrared auxiliary system, which had a field of 1°, presented the entire lunar disk on a separate monitor on the control panel. If an infrared event had occurred, it would have been easily visible as a bright spot on the monitor, and the primary electro-optical train would have been directed to the position of the event for detailed observations in other wavelength regions.

Because many of the Astro-Net reports pertained to activity on the dark (Earth-lit) portion of the lunar surface, the lunar surveillance program was further extended in March 1966. While the S-10 and S-20 photocathodes were of sufficiently high sensitivity and resolution for the Sun-lit surface, another image orthicon tube of higher sensitivity was used each month over the 7-day period centered on new Moon to permit observing and photographing the Earth-lit portion. Despite the faintness of this region, photographs were easily obtainable in yellow light with integration times as short as 1/30th of a second. An example of the results attainable is shown in figure 7.

To extend the period of observation of the Moon each night, a series of diaphragms was added to the 24-in. telescope to permit continued observing when the Moon was only 2° to 3° above the horizon. Astro-Net activities were high at this time. The amateurs were reporting events, and the Corralitos staff also checked their reports by many observations with a 12-in. *f*/16 Cassegrain, a 5-in. *f*/15 refractor, and a 10-in. Maksutov telescope, all located at the Corralitos site.

In June 1966, extensive review was made by the technical staff of the feasibility of changing the image orthicon readout system. The original image orthicon chain underwent modifications at this time that did result in an optimization of system stability and a significant increase in gain. While this was being done, the feasibility of increasing the red-blue blink rate

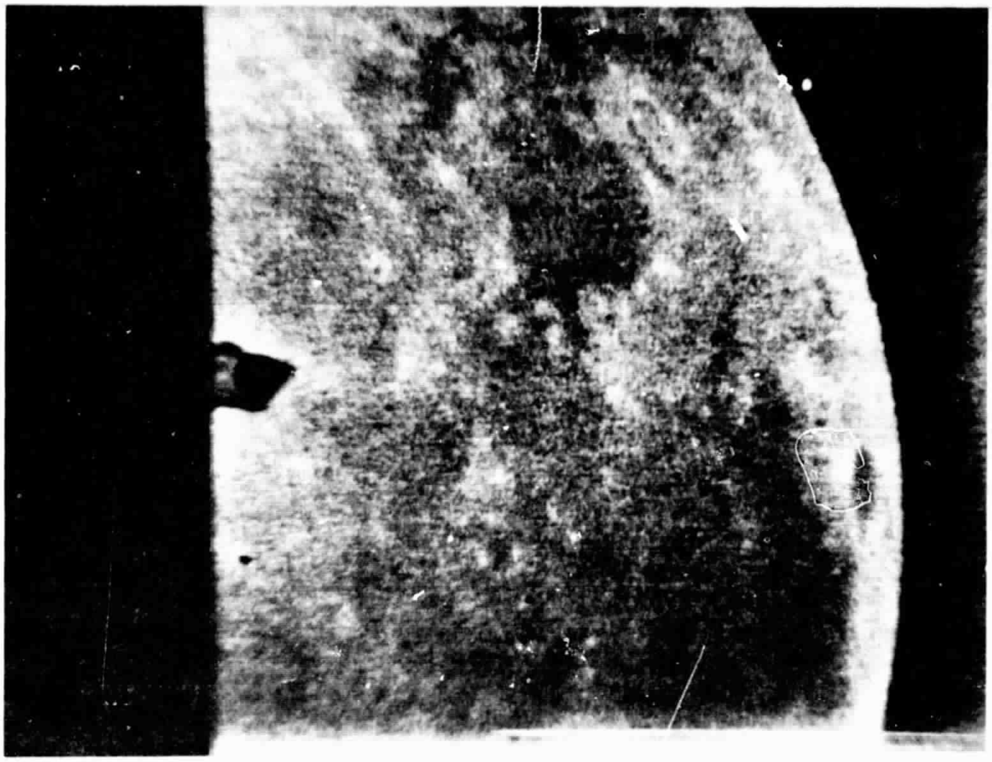

Figure 7.–A portion of the Earth-lit lunar surface as seen with the orthicon system.

was extensively investigated. It was concluded that a second identical image orthicon camera should be added so that two identical cameras, one equipped with a red filter and the other with a blue filter, could be tied into the same control circuitry. By means of a beam-splitting device and switching circuitry, it would then be possible to present first a red and then a blue picture to the visual monitor at a blink rate of 1/20th of a second since the scan rate of the cameras was to be 20 frames per second. Approval was granted for further research into this modification proposal and construction was begun on a working model.

Relocation of the Organ Mountain Observatory instrumentation and telescope was totally completed in April 1967 when Northwestern University received the title to the 160-acre tract of land at Corralitos Observatory from the Department of the Interior. The relocated system became operational on June 15, 1967. The completion of the testing and alinement of this second telescope at the Corralitos site provided a supplemental detection system and backup for the lunar patrol.

The first significant observational event of the lunar patrol occurred on April 21-22, 1967. The Corralitos staff found the blue image of the Moon anomalously bright; this was first thought to be ascribable to lunar luminescence in the near ultra-violet (described in detail later in this report).

The two-camera system was completed early in 1968 and underwent considerable testing, both in the laboratory and in the field at Corralitos. It became apparent that additional circuit modifications were necessary to provide linearity adjustments and high gain video amplifiers. Observational tests at Corralitos showed that mechanical matching of the image orthicon tubes was essential for display linearity and, hence, a balanced blinking effect.

Justus Dunlap was appointed Resident Director of the Corralitos Observatory in April 1968 and continued his supervision of the field activities of the lunar surveillance program.

Modifications to the twin camera system were completed in August 1968; it was returned to Corralitos for testing purposes and results showed that previous problems of video gain for preamplifier optimization had been overcome. However, the mechanical and sensitivity mismatching of the cameras remained and so it was not incorporated into the active system. Mechanical matching was improved by the addition of waveform corrections to one of the cameras and by the use of selected matching image orthicon tubes. Two such tubes, one a GE 7814 and the other a GE 7538, were obtained in June 1968. The former had an S-20 photocathode and the latter an S-10 photocathode surface, which were to be used in the "red" and "blue" cameras, respectively. The use of the tubes with the different photocathodes, though necessitated by budgetary considerations, was ideal from the standpoint of spectral response.

Unfortunately, while thin spectral responses were ideal, the sensitivities of the two different photocathodes were not sufficiently well matched to provide accurate blinking. The major difficulty was found to be the nonuniform sensitivity across the photocathode surfaces, a problem that was compounded when these tubes were used in the high-resolution Corralitos program, which emphasized the dissimilarities between any two tubes. Therefore, it seemed unlikely that the two-camera system could be developed to such a point where it would replace the original output display system, and with considerable reluctance it was not incorporated into the active observing program.

In May 1969, a complete Ealing 16-in. Cassegrainian optical system was acquired to replace the 12-in. telescope brought from Organ Mountain Station. The larger aperture and higher quality optics proved a worthy complement of the primary surveillance system and were also used extensively to develop image orthicon techniques for planetary studies.

Experience had shown that observations of the Moon when it was too near to either horizon were of little value as long atmospheric paths caused marked color imbalances, with the red images being grossly enhanced over the blue, making detection of any actual color change nearly impossible. Therefore, instead of observing the Moon from the time when it was 7° above the eastern horizon to 7° above the western horizon, starting December 1, 1970, this limit was changed to 10° to 12° for each horizon. Also at this time, greater emphasis was placed on the observations of critical areas such as Aristarchus and Alphonsus and on the terminator regions rather than giving essentially equal time to all areas of the Moon. The entire Moon was still surveyed several times during each observing session.

In late 1970, the gain of the image orthicon system was significantly increased by the use of a new high-gain, low-noise, wide-bandpass amplifier with remotely controlled amplification. The remote control permitted maintenance of a large output signal over a wide range of light levels, thus minimizing pickup noise in the camera cable. The maximum usable voltage gain was about 200, corresponding to a 1-V output signal for a 1-μA input signal.

As no LTP's within the detection capabilities of the Corralitos instrumentation had been detected over an extended period and the Apollo Manned Lunar Landing program had come to an end, emphasis was removed from the constant lunar surveillance program. Although the last nightly routine observations were made April 26, 1972, occasional observations of areas considered most likely to show changes were made until December 1972. A detailed account of actual man-hours of observations with the primary electro-optical system is given in table 1.

Table 1.—*Actually Fully Operational Man-Hours of Observing Time With the Primary Electro-Optical System*

Period included	Hours
Oct. 27 to Nov. 30, 1965	240
Dec. 1, 1965, to May 31, 1966	560
June 1 to Nov. 30, 1966	400
Dec. 1, 1966, to May 31, 1967	550
June 1 to Nov. 30, 1967	450
Dec. 1, 1967, to May 31, 1968	500
June 1 to Nov. 30, 1968	560
Dec. 1, 1968, to May 31, 1969	740
June 1 to Nov. 30, 1969	622
Dec. 1, 1969, to May 31, 1970	550
June 1 to Nov. 30, 1970	368
Dec. 1, 1970, to May 31, 1971	450
June 1 to Nov. 30, 1971	224
Dec. 1, 1971, to Apr. 26, 1972	252
Total	6466

SUMMARY OF OBSERVATIONAL RESULTS

Despite the extensive and detailed program for the detection of LTP's, no color or feature changes within the detection capabilities of the instrumentation were observed on the lunar surface within the period of surveillance. With the 24-in. reflector, under good seeing conditions, the observing staff would have been able to detect distinct changes occupying somewhat more than 1 arcsec on the lunar surface. Control observations of other objects (such as the bands of Jupiter) indicated that the system was capable of detecting relatively minor color changes. Laboratory tests showed that a 5-percent change of intensity in any 100-Å bandwidth was easily detectable by an observer. Visual observations of the monitor screen were continuous, supplemented by photographs of the readout for frequent record purposes. Some 45 000 photographs, 15 000 in each of the three colors, were obtained.

Therefore, one must reexamine the superabundance of amateur reports of color and albedo phenomena. It soon became the consensus among the observing staff members that the majority of Astro-Net reports of surface brightenings were the effects of variable seeing conditions, particularly after the visual observer at Corralitos noted just such a brightening near Aristarchus on April 26, 1966. Examination of this area with the primary orthicon chain proved the "brightening" to have been a small bright crater that, because of image excursion, blended into the surrounding area most of the time. Occasionally the seeing would stabilize and allow it to be resolved, resulting in an apparent brightening in the area. This effect would undoubtedly be more pronounced with the smaller instruments utilized by the Astro-Net observers.

There also appeared to be a definite correlation between observations at low lunar altitudes (30° horizon distance or less) and LTP's as reported by the Astro-Net personnel. This suggests the probability that most of their reports were of incidents created by local atmospheric conditions.

Table 2 illustrates the log of LTP's, reported by various sources, and the status of the Corralitos electro-optical system insofar as confirmation is concerned. Many of the reports were recorded in articles by either Middlehurst (1968) or Cameron (1972) or real-time Astro-Net reports. The Corralitos staff could not confirm a single one of these observations. It must be recognized that the visual observations by amateurs were with smaller instruments than those available at the Corralitos facilities and that they did not have available the ability to vary the contrast as could be done at Corralitos, which was of great assistance in checking the reality of suspected changes. The fact remains that, using far better equipment in a systematic scheduled continuous program of observation, not a single event that was reported could be confirmed.

It is of interest to obtain a perspective of the relative merits of the programs by comparing the Corralitos and the Moon-Blink and Astro-Net programs because they are similar in concept. The Corralitos observers worked with far greater telescope apertures than the amateur groups. This is an important point since perhaps the most respected reports of lunar changes are those of Greenacre and Barr in late 1963. Their observations were made with a 24-in. telescope and confirmed with the Perkins Observatory 69-in. reflector. However, their reported phenomenon was quite invisible in the 6-in. finder telescope and smaller instruments.

Another important point is the location from which the observations were made. The majority of the Moon-Blink observers were located at or near sea level, in or near large cities. On the other hand, the Corralitos site is quite exceptional and easily ranks highly among American observatories in both excellence of seeing conditions and the number of observable hours throughout the year.

The observing method of the Corralitos operation obviously was superior to that of the Moon-Blink and Astro-Net programs. Observations were carried out by viewing the TV monitor screen rather than through the telescope eyepiece. Because the cameras were permanently mounted at the Corralitos monitors, photographic records could be (and were) made simultaneously to confirm the visual observations. Nearly instantaneous photographic capabilities were not available at the Moon-Blink or Astro-Net stations. The filter system of the Moon-Blink observers consisted of two rapidly rotating filters in the optical path—Wratten gelatin filters nos. 29 and 44A. As they were not mounted in optical glass, their nonuniform surfaces permitted constant excursion of the visual image, contributing greatly to unstable images and eyestrain. Finally, none of the Moon-Blink or Astro-Net stations surpassed the supportive facilities of Corralitos.

Although exact counts are not available, the total number of hours spent in either of the two amateur programs surveying the Moon probably was much less than the total number of hours spent at Corralitos although many Moon-Blink and Astro-Net stations were in operation simultaneously.

The first instance of an unusual phenomenon observed through the Corralitos electro-optical system occurred early in 1967. An enhanced lunar intensity was recorded on April 21 and 22, 1967, by the Corralitos staff. This phenomenon occurred 48 to 82 hr before the total lunar eclipse of April 24, 1967. Evidence of a UV excess was apparent at the start of the observing session, at approximately 2:30 UT, on April 21, 1967, when the luminosity gradient ranged from 0 percent at the terminator to 30 percent at the subsolar point in the illuminated limb of the Moon, relative to the red and visual images. This condition persisted throughout the night until approximately 9:30 UT, and the Moon was only 10° to 12° above the horizon when the atmospheric attentuation had so reduced the blue image that the program was terminated due to bad seeing. On the second night's observation of this event, conditions were almost identical, with clear skies throughout the night but with the blue images now showing approximately a 10 percent increase over the visual and red images at the terminator and increasing to 25 to 30 percent at the subsolar point. On April 23, 1967, the UV excess had completely disappeared, rendering a well-balanced and stable three-color picture. Although the bandpass of the blue filter ranges from 3700 to 4900 Å, it is logical to assume that the excess occurred at a wavelength shorter than 4000 Å, as no excessive bluing could be detected visually with optical aid. As the luminosity gradient ranged from 30 percent on the bright limb of the Moon to 0 percent on the terminator, this should have been apparent visually if the wavelength were longer than 4000 Å. Figures 8 through 10 illustrate the bluing effect.

Examinations of the electronic, filter, and optical systems showed nothing unusual. On April 20, 1967, the three-color filter system had been found to be well balanced throughout the night's observing session. Therefore, the possibility of an equipment malfunction was ruled out. Observations of this bluing phenomenon were coincidental with the Lyrid meteor shower and also a forest fire in the Lincoln National Forest, 100 miles east of the Corralitos Observatory. However, neither of these events were thought to have produced the bluing. The energy requirements necessary to produce the effect could not have been met by the meteor shower. Smoke haze was ruled out because photometric measures of the sky background several degrees away from the Moon showed no evidence of visual or red attenuation. Significant solar magnetic storm activity was

Figure 8.–The bluing in Mare Nectaris in the blue spectral region.

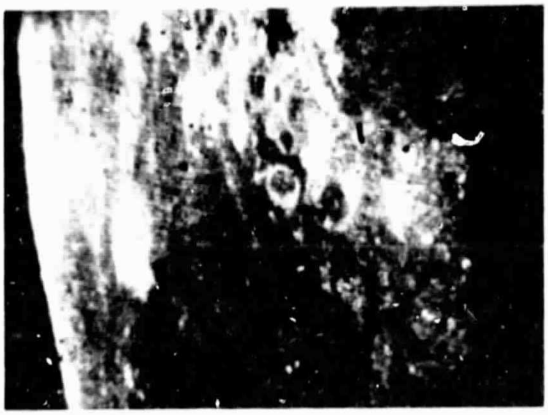

Figure 9. The bluing in Mare Nectaris in the visual spectral range.

Figure 10. The bluing in Mare Nectaris in the red spectral range.

n't reported in the days preceding the event to create increased lunar luminescence in the near UV continuum. If, in fact, the lunar luminescence was indigenous to the Moon, a possible source of excitation to consider might be found in the concentration of charged particles, trapped in the tail of Earth's magnetosphere, as the Moon passed through. However, it is doubtful that sufficient energy could be developed in this manner to produce the general bluing observed. The cause of the general bluing is, then, unknown, and it may well be some as yet undetermined terrestrial atmosphere effect. It does seem most unlikely that the entire Moon would have become bluer in response to a bona fide lunar surface phenomenon.

On December 7, 1968, shortly after full Moon, a distinct bluing was detected by the Corralitos observing staff around the craters Aristarchus, Kepler, and Copernicus, the effect being strongest at Aristarchus. It lasted several days. A careful check was made of the three-color blink system and image orthicon chain. Examination of the record photographs showed about a 30 percent change in intensity with the blue filter as compared with the other two filters, explainable only in part by the technique used in photographing the monitor, a method analogous to the "stacking" of negatives to bring out additional details. In early January 1969, and on several other occasions (fully stated in table 2), during the same lunar phase and under the same lighting conditions, the same phenomenon was again detected at Corralitos. This is further evidence that it was not a systemic condition. While this blue excess has not been confirmed elsewhere, the staff knows of no organized attempt at outside confirmation. Attempts to correlate the blue excess with solar activity and with several other factors, to seek out possible periodicities, were fruitless. However, at the times of observation, the full Moon appeared at the point in its orbit which was the most northerly of any time within the observing program and therefore was observed through the least airmass. Consequently it would appear bluer than when observed along longer pathlengths. This may explain why the features of highest albedo, namely Aristarchus, Kepler, and Copernicus, showed the greatest bluing.

A note of explanation concerning table 2 is in order. The bulk of amateur observations of LTP's were reported in 1966 and 1967, the number diminishing rapidly afterward and finally reaching the point where no observations of LTP's came to the attention of the Corralitos staff during 1971 and 1972. This reflected an increasing disinterest among amateur lunar observers due, no doubt, to the lack of professional confirmation of their reports and also to the termination of the Apollo program. Even organized amateur groups such as the Argus Astro-Net had terminated their lunar observing programs and returned to their primary interest of radio communication.

Table 2. *Log of Corralitos Efforts to Confirm Reported LTP*

Date	Report	Observer	Corralitos
1966, Jan. 23	Brightenings near Aristarchus	Astro-Net	Clouded out. Monitored next 3 nights in region, but no changes seen.
1966, Feb. 7, 0h, 10m	Violet hue in Aristarchus	Bartlett	90 percent cloud cover.
1966, Feb. 25, 4h, 10m	Flashes, rays of light, large area brightenings, pulsating blue-white disk, double image of Aristarchus	Astro-Net	Clouded out.
1966, Feb. 27	Flashes in Grimaldi	Astro-Net	Monitoring; not confirmed.
1966, Mar. 29, 21h, 0m	Brightening in Aristarchus	Bornehurst	Still daylight. 6 hr later took photographs which showed nothing unusual.
1966, Apr. 1, 3h, 22m	Coloration in Aristarchus	Astro-Net	Monitoring; not confirmed.
1966, Apr. 1, 3h, 29m	Reddish-brown spot in eastern part of Plato	Astro-Net	Monitoring; not confirmed.
1966, Apr. 1, 5h, 46m	Reddish-brown spot on east floor of Plato for 10 s	Astro-Net	Could not move telescope in time.

Table 2.–*Log of Corralitos Efforts to Confirm Reported LTP–Continued*

Date	Report	Observer	Corralitos
1966, Apr. 2, 23h, 30m	Anomalously bright peak in Aristarchus	Brown	Still daylight.
1966, Apr. 3, 23h, 0m	Anomalously bright peak in Aristarchus	Brown	Still daylight.
1966, Apr. 12, 1h, 5m	Red flashes in Grimaldi	Whippey	Monitoring; not confirmed.
1966, Apr. 17		Cross	Not in operation.
1966, Apr. 25 to 27	Flashes on Earth-lit portion	Astro-Net	Monitoring; not confirmed.
1966, Apr. 26	Brightening near Aristarchus	Visual observer at Corralitos	Found to be a small bright crater which, due to image excursion, blended into surroundings most of the time. Stable seeing allowed it to be resolved occasionally.
1966, Apr. 28	Red glows in Gassendi	Smith	Monitoring; not confirmed.
1966, Apr. 30 to May 2	Red glows and bright spots in Gassendi	Paterson, Brown, and Sartory	Monitoring; not confirmed.
1966, May 1, 22h, 10m	Brightening, red spots northwest of Aristarchus	Paterson, Brown, and Sartory	Still daylight. 6 hr later took photographs of a bright ridge in the right position which was also bright in the lunar atlas under similar lighting conditions.
1966, May 3	Red glows in Gassendi	Smith	Monitoring; not confirmed.
1966, May 24	Flashes and brightenings halfway between Aristarchus and Grimaldi and on limb south of Grimaldi	Astro-Net	Monitoring; not confirmed.
1966, May 27, 21h, 10m	Red patches in Alphonsus	Sartory and Moore	Still daylight.
1966, May 28	Red glow in Gassendi	Smith	Monitoring; not confirmed.
1966, May 29	Red glow in Gassendi	Smith	Monitoring; not confirmed.
1966, May 30, 20h, 52m	Orange patch in Gassendi	Sartory	Still daylight.
1966, June 1, 3h, 20m	Bright flashes of short duration and bluish color near Aristarchus	Bartlett	Clouded out.
1966, June 2	Brownish-yellow spot on rim of Aristarchus	Jaeger	Clouded out.
1966, June 3, 6h, 10m	Bright flashes near Aristarchus	Astro-Net	Clouded out.
1966, June 26, 4h, 30m	4880±50 Å band seen in absorption spectrum of central peak of Aristarchus	Harris and Arriola	Clouded out.
1966, June 27	Coloration in Plato	Hedley, Robinson, and Sartory	Still daylight.
1966, July 4, 6h, 25m	Granulation and coloration in Aristarchus	Bartlett	Monitoring; not confirmed.
1966, July 10, 2h, 0m	Bright streak in Triesnecker	Allen	Monitoring; not confirmed.
1966, July 29, 3h, 40m	Red spot in Aristarchus	Simmons	Clouded out.
1966, July 30, 6h, 32m	Red color in Aristarchus, Herodotus, and Schröter's Valley	Arriola and Cross	Clouded out.

Table 2.–*Log of Corralitos Efforts to Confirm Reported LTP–Continued*

Date	Report	Observer	Corralitos
1966, Aug. 4 to 5	Red color in Plato	Corvan and Moseley	Clouded out.
1966, Aug. 27	Flashes near Alphonsus	Astro-Net	Monitoring; not confirmed.
1966, Aug. 27	Changes in Ross B from hour to hour	Astro-Net	Found to be due to changing angle of illumination of the craterlet.
1966, Aug. 28	Activity in Alphonsus	Astro-Net	Clouded out.
1966, Aug. 30, 5h, 17m	Brownish color in Aristarchus	Bartlett	Monitoring; not confirmed.
1966, Sept. 1	Flashes and brightenings in Aristarchus	Astro-Net	Monitoring; not confirmed.
1966, Sept. 2, 0h, 0m	Red patches in Gassendi	Moore et al.	Clouded out.
1966, Sept. 2, 3h, 47m	Weak glows and flashes in Alphonsus	Whippey	Monitoring; not confirmed.
1966, Sept. 3, 3h, 55m	Coloration in Gassendi	Moseley	Monitoring; not confirmed.
1966, Sept. 23	Red patch in Gassendi	Sartory	Monitoring; not confirmed.
1966, Sept. 25, 3h, 46m	Red patches in Gassendi	Moore and Moseley	Still daylight.
1966, Sept. 25, 3h, 46m	Coloration in Plato	Moseley	Still daylight.
1966, Sept. 25, 20h, 20m	Red patches in Gassendi	Moore and Moseley	Still daylight.
1966, Sept. 25, 23h, 12m	Coloration in Plato	Moseley	Still daylight.
1966, Oct. 25, 22h, 30m	Bright area near Ross D	Cross	Still daylight.
1966, Oct. 26 to 27, 23h, 45m to 0h, 30m	Violet hue in Aristarchus	Gordon	Still daylight.
1966, Oct. 27, 2h, 45m	Red spot near Aristarchus	Delano	Monitoring; not confirmed.
1966, Oct. 29, 0h, 45m to 1h, 30m	Red spot in Copernicus	Walker	Still daylight.
1966, Dec. 16, 22h, 0m	Blue and red coloration in Aristarchus	Farrant	Still daylight.
1966, Dec. 22, 6h, 15m	Colorations in the floors of Messier and Pickering	Kelsey	Clouded out.
1966, Dec. 23, 5h, 15m to 7h, 10m	Streaks and spots in Plato	Kelsey	Monitoring; not confirmed.
1966, Dec. 27, 6h, 47m	Spots in Gassendi	Kelsey	Clouded out.
1967, Jan. 18 to 19	Brightening in Aristarchus	Delano	Monitoring; not confirmed.
1967, Jan. 21, 20h, 0m	Brightening near wall in Gassendi	Moore et al.	Still daylight.
1967, Feb. 17, 17h, 47m to 18h, 12m	Brightening on the floor of Alphonsus	Moore and Moseley	Still daylight.
1967, Feb. 19, 20h, 30m to 20h, 40m	Red color in Gassendi	Moore and Moseley	Still daylight.

Table 2.–*Log of Corralitos Efforts to Confirm Reported LTP–Continued*

Date	Report	Observer	Corralitos
1967, Feb. 19, 20h, 30m to 21h, 11m	Bright glow in Alphonsus	Moseley	Still daylight
1967, Feb. 23	Bright flashes near Aristarchus	Astro-Net	Monitoring; not confirmed.
1967, Mar. 21, 19h, 15m to 21h, 20m	Bright flashes near Aristarchus	Astro-Net	Monitoring; not confirmed.
1967, Mar. 22, 19h, 40m	Red color in Gassendi	Moseley	Clouded out.
1967, Mar. 23, 18h, 40m to 18h, 55m	Brightening in Gassendi	Sartory and Farrant	Still daylight.
1967, Mar. 23, 19h, 45m	Red color outside wall of Cobrahead	Moore, Moseley, and Farrant	Still daylight.
1967, Mar. 23, 19h, 45m to 19h, 55m	Red glows in Aristarchus	Moore et al.	Still daylight.
1967, Apr. 15, 19h, 15m to 21h, 0m	Aristarchus very bright	Classen	Still daylight.
1967, Apr. 21, 2h, 30m to 9h, 30m	UV excess of Moon	Corralitos image-orthicon (I-O) system	Condition existed until Apr. 23, 1967. See detailed explanation in text.
1967, Apr. 21, 19h, 0m to 21h, 20m	Brightening in Aristarchus; red coloration on the Cobrahead	Moore et al.	Monitoring; not confirmed.
1967, Apr. 22, 21h, 0m	Aristarchus visible to the naked eye	Schöbel and Classen	Still daylight.
1967, Apr. 22	Aristarchus visible to the naked eye	Classen	Monitoring; not confirmed.
1967, May 20	Elongated spot in Gassendi	Kelsey	Still daylight.
1967, May 20, 20h, 15m to 21h, 15m	Red spots in Aristarchus	Darnell	Still daylight.
1967, May 21, 6h, 40m to 7h, 25m	Red spot in Aristarchus	Andersen	Clouded out.
1967, June 16	Activity in Plato	Astro-Net	Monitoring; not confirmed.
1967, June 18, 21h to 24h	Red area outside Gassendi	Whippey	Still daylight.
1967, Aug. 13, 21h, 0m	Glow in Alphonsus	Horowitz	Clouded out.
1967, Sept. 11, 0h, 32m to 0h, 45m	Black cloud in Mare Tranquillitatis	Montreal group	Still daylight.
1967, Sept. 11, 0h, 45m	Yellow flash in Sabine	Jeans	Clouded out.
1967, Sept. 11, 20h, 32m to 20h, 40m	Bright crater rim in Copernicus	Jeans	Clouded out.
1967, Sept. 16, 23h, 50m to 23h, 55m	Red color in Aristarchus	Delano and Seliger	Still daylight.

Table 2.–*Log of Corralitos Efforts to Confirm Reported LTP–Continued*

Date	Report	Observer	Corralitos
1967, Sept. 17, 2h, 5m to 2h, 21m	Red color in Aristarchus	Delano	Monitoring; not confirmed.
1967, Oct. 10, 2h, 15m	Bright moving spot near Ross D	Harris	Monitoring; not confirmed.
1967, Oct. 13, 19h, 17m	Flashes on the terminator	Henshaw	Monitoring; not confirmed.
1967, Oct. 19, 5h, 0m	Anomalous brightening of Kepler with respect to Aristarchus	Harris	Monitoring; not confirmed.
1967, Nov. 15, 5h, 40m	Brightening and red color in Aristarchus (Harris: spectra showed nothing unusual)	Cross, Tombaugh, and Harris	Monitoring; not confirmed.
1967, Dec. 13, 21h, 40m	Red and violet colors in Aristarchus	Jean	Still daylight. Nothing unusual observed later that night.
1967, Dec. 18, 3h, 31m to 4h, 7m	Violet color on limb	Coallick	Snow made system nonoperational.
1968, Jan. 8, 16h, 30m to 16h, 50m	Blue-violet color in Tycho	Jean	Snow made system nonoperational.
1968, Jan. 13, 1h, 0m to 8h, 0m	Blue-violet color on limb and in Herodotus and Tycho	Jean	Monitoring; not confirmed.
1968, Mar. 14, 1h, 32m to 2h, 6m	Bright areas near Copernicus	Olivarez et al.	Monitoring; not confirmed.
1968, Apr. 11, 22h, 0m	Blue and red coloration in Aristarchus	Farrant	Still daylight.
1968, July 18, 0h, 50m to 1h, 30m	Red glow and obscuration in Aristarchus	Moore et al.	Clouded out.
1968, Dec. 4, 19h, 0m to 20h, 15m	Aristarchus and Plato, anomalously bright and red	Dall'Ara	Equipment failure prevented observations.
1968, Dec. 7	Bluing around Aristarchus	Corralitos I-O system	See detailed explanation in text.
1968, Dec. 23, 2h, 30m	Brightening in Aristarchus	Harris	Moon not observed.
1969, Jan. 4	Bluing around Aristarchus	Corralitos I-O system, Smith and Thomas	See detailed explanation in text.
1969, Apr. 1, 18h, 35m	Spectrum of red spot in Aristarchus observed; C_2 and N_2 identified.	Kozyrev	Moon not up yet. Later, through clouds, Aristarchus seemed bluer but could be the result of the clouds. Next night cloudy, although Moon seemed blue through clouds.
1969, May 3	Bluing around Aristarchus	Corralitos I-O system, Smith and Gallivan	Visible on monitor but immeasurable on photographs. See detailed explanation in text.

Table 2.–*Log of Corralitos Efforts to Confirm Reported LTP–Concluded*

Date	Report	Observer	Corralitos
1969, May 20, 4h, 27m	Brightening and pulsations in Aristarchus	Cross	Moon nearly on the horizon; tracking Apollo 10 at the time.
1969, June 30 to July 2	Bluing around Aristarchus	Corralitos I-O system, Altizer and Abrabanel	Visible on monitor but immeasurable on photographs. See detailed explanation in text.
1970, Jan. 23 to 25	Bluing around Aristarchus	Corralitos I-O system, Rogers and Thomas	Visible on monitor but not photographable due to clouds.
1970, Feb. 22 to 24	Bluing around Aristarchus	Corralitos I-O system, Thomas and Stump	Visible on monitor but not photographable due to clouds.
1970, Aug. 13	Brightening in Lassell	Astro-Net	Monitoring; not confirmed.
1970, Aug. 14	Brightening in Lassell	Astro-Net	Monitoring; not confirmed.
1970, Aug. 17	Unusual activity in Fra Mauro region.	Astro-Net	Monitoring; not confirmed.

Appendix A

THE CORRALITOS OBSERVATORY NONLUNAR SURVEILLANCE PROGRAMS

OBSERVATIONS OF NASA-SPONSORED PROJECTS

In conjunction with the primary lunar transient phenomena program, it seemed appropriate to use the facilities of the Corralitos Observatory when the Moon was not available for observations in support of other NASA programs, for example, the barium cloud experiments, the Apollo capsules, and space dumps. The first attempted observation of any NASA-launched space vehicle by the Corralitos Observatory was made quite early in the program. On June 2, 1966, the area of the Surveyor 1 lunar landing site was observed. The area of the intended landing site had been observed on several nights prior to the landing as well as the time of and after the landing. No albedo or other surface changes resulting from the firing of the lunar vehicle retrorockets could be detected with the electro-optical system. The resolution of photographs taken at that time was standard, with a resolution of between 1 and 2 arcsec.

The tracking abilities of the orthicon system were amply demonstrated in late December 1968 when the Corralitos staff tracked the Apollo 8 capsule on each of the first three nights after launch. On the first night, the detached carrier rocket and several independent and associated parts were visible. On a few frames of the record photographs, up to five separate Apollo 8 objects are visible. The integration times, even when Apollo 8 was approaching the Moon on the third night after launch, were on the order of 1 s.

During the Apollo 10 mission the Corralitos program was linked with the CBS news network. The Apollo 10 capsule was observed on the first night after launch but later attempts to detect it in lunar orbit were unsuccessful. Some 300 photographs of the capsule were obtained on May 25, 1969, on its return flight.

Weather hindered attempts to track Apollo 11 although the command module was tracked July 23, 1969, on the first night of its return trip.

The Apollo 12 mission was fully covered on every night that weather permitted. On the first night, the SIVB (third stage engine), and the jettisoned command and service module and lunar module (CSM and LM), spacecraft lunar module adapter (SLA) panels were photographed, sometimes with all four objects appearing on the same record frame. The capsule was followed on the second and third nights as it approached the Moon. On November 15, 1969, when the spacecraft was about 110 000 km from Earth, the Apollo 12 water dump was successfully photographed and the expansion of the water cloud was clearly apparent. A full report of this is available in a Bellcomm, Inc., report (Buffalono, 1970). Three of the Corralitos photographs of the water dump were published in *Sky and Telescope* (1970). Corralitos also surpassed the Soviet Union's claim of setting a distance record in photographing a space flight. Soviet scientists announced, in October 1969, that they had successfully photographed the spacecraft Zond 8 at the distance of 216 000 miles from Earth. However, in tracking Apollo 12, the Corralitos Observatory was able to photograph the capsule at a distance of 229 400 miles from Earth.

During the Apollo 13 launch period, one of the telescopes again was employed to follow the capsule on its journey to the Moon. On the second night after launch the explosion of an oxygen tank was observed when the Corralitos observers noted an unusual brightening of the capsule. Photographs were taken immediately, the first photograph just 7.8 s after the explosion. Numerous photographs were taken subsequently, and when the nature of the emergency became known, the films were dispatched to Houston for study.

Routine backup to other flight observations was continued with the launch of Apollo 14 in January

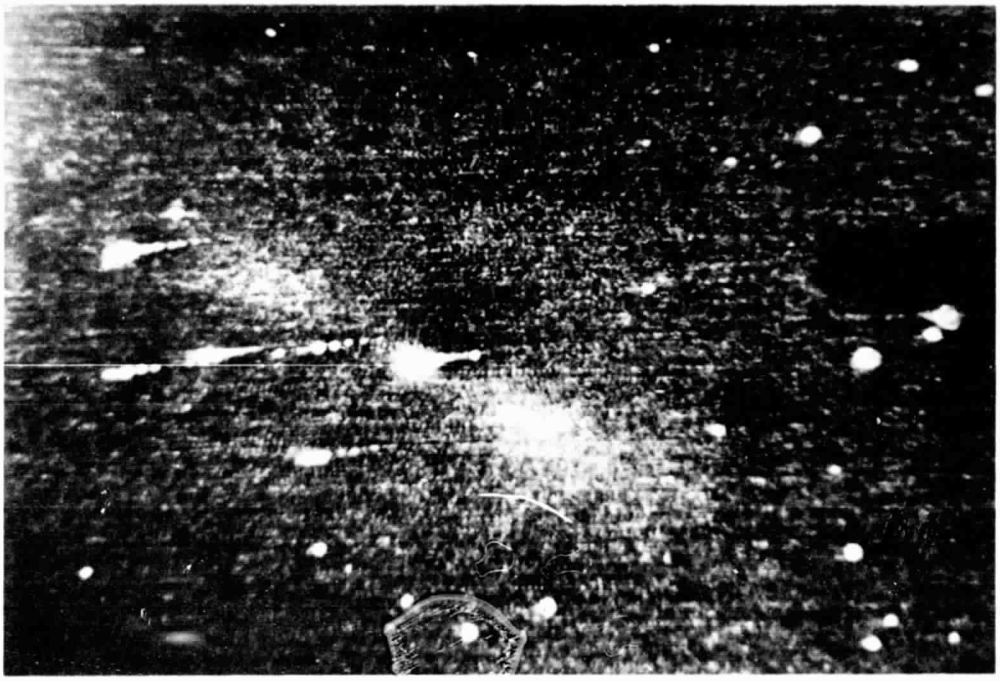

Figure A-1.–Water-dump, Apollo 14 capsule, SB4, and four associated SLA panels with the orthicon system.

1971. The capsule and associated SLA panels were observed on the first night after launch and the capsule was observed on the next two nights until its close approach to the Moon, where scattered light from the lunar surface made observations impossible. Separation of the spacecraft capsule from the SIVB rocket engine was easily observable. A photograph of the Apollo 14 capsule and five associated objects appears in figure A-1.

INDEPENDENT PROGRAMS

Other programs were undertaken when the Moon was not visible, weather permitting. The most important of these was the real-time search for supernovae. Both the 24- and 16-in. Cassegrainian telescopes at Corralitos were equipped for a real-time search for supernovae using image orthicon techniques. The National Science Foundation provided funding for personnel and for the semiautomation of the 24-in. telescope, whose motions were controlled by a PDP-8/S computer. The 16-in. telescope was remotely controlled manually. Detection of a supernova was a relatively simple matter. It is well known that at maximum a supernova eruption can attain a brilliance rivaling that of the total integrated light of the parent galaxy. Therefore, resolution of the supernova from the nucleus was generally possible, since supernovae are very frequently observed in the outlying regions of a galaxy.

The technique of searching involved direct visual comparision of the storage tube readout screen with master photographs. In rich galaxy cluster regions, photographs were taken of the screen and later compared with master photographs to insure a complete study of the region down to a limiting magnitude of 18. Concerning the ultimate limiting magnitude of the present Corralitos system, by using a combination of storage and multiexposure techniques, it was possible to reach the limit of the *Palomar Sky Atlas* in a total integration time of less than 10 s. Typical integration times used in the supernova search were 2 to 3 s. An added feature of the program was the technique of electronically suppressing the apparent nebulosity of the galaxy, thus enhancing the detected stellar images within the field.

First funding of this project occurred on June 1, 1967. Actual observations were carried out from September 7, 1967, to March 14, 1972. The program comprised the repetitive observations of some 1300 galaxies when available. During the entire period of the search, 10 supernovae were discovered, one of these being an independent co-discovery. Photographs of one of the Corralitos discoveries are shown in figures A-2 and A-3. The supernovae discovered at the Corralitos Observatory are detailed in table A-1.

In connection with this program, a unique auxiliary photomultiplier-photometer which used the image orthicon readout as its finding field was developed. For the photometry of individual objects, a small pickoff mirror was placed off to one side but immediately in front of the photocathode of the image orthicon. Using the entire field presented on the cathode ray tube, the observer identified the object to be examined and occulted the target object by the shadow of the small mirror that appeared on the screen as a black spot. When so occulted, the light of the target object was deflected into a standard photomultiplier pulse-counting device equipped with UBV filters and the result was digitally displayed on the control panel. The greatest advantage of this photometric procedure for individual objects is that the entire field of the orthicon was used as a finder field and positive identification could be made with ease. Finally, the observations themselves were made in the comfort of the control room, a circumstance which added greatly to procedural efficiency. Other uses of this photometer (e.g., photometry of planetary details, asteroids, and stellar fields and point-by-point photometry of extended objects), immediately suggest themselves.

After termination of the Apollo program, other projects of inherent interest to NASA were undertaken. Most of these were concerned with possible new applications of the image orthicon in astronomy. This included an investigation of short-integration time planetary surface image orthicon photography. During the lunar surveillance program, control observations in the different colors had shown that the system was capable of detecting relatively minor color changes. Simple eyepiece projection from the 24-in. telescope permitted high resolution studies of planetary details such as those illustrated in figures A-4 and A-5. It should be noted that these observations were made several months after the oppositions of Jupiter and Saturn, the planets of primary interest.

As of June 1972, a pulser for activating the photocathode of the image orthicon for intervals ranging from the normal rate of 1/30th of a second to 5 ms was constructed at the Dearborn Observatory for use at Corralitos. Practically, this meant that integration times much shorter than ordinarily possible with the image orthicon could be used to observe very-short-term variations in astronomical objects or to freeze instants of good seeing. Accordingly, observations of the optical variations of the Crab Nebula pulsar were undertaken and the variations were indeed observed quite readily. However, the system was designed for observations of this particular pulsar, and the lack of funds did not permit development of crystal-controlled oscillation, hence limiting the system's usefulness for other applications.

The usefulness of the image orthicon in "non-objective" spectroscopy was investigated. Experimentation initially was with a 10-in. objective prism attached to the 12-in. telescope, and acceptable spectra of bright stars were obtained by a single trailing of the image for a few seconds across the photocathode. Recently, a small transmission grating has been placed in the converging beam of the 24-in. telescope, just a few inches from the cathode of the image orthicon. Figure A-6 shows the results attainable for an emission line object such as a planetary nebula. This method of spectroscopy is probably most valuable for the detection of emission line objects and for those astronomical objects whose radiation is concentrated in narrow wavelength regions. Image-orthicon non-objective spectroscopy could be used for the detection and study of short-term variations in quasars, compact galaxies, and peculiar and flare stars, where speed of detection is essential.

An investigation of the detection and possible positional accuracy measures of faint and rapidly moving asteroids was also undertaken. Once detected, photometric measures of these objects were readily found by means of the photometer described in the discussion of the supernova search. Positional measures were rendered practical since integration times of even faint and rapidly moving asteroids were so short with the image orthicon that motion was not visible and the stars and asteroid appeared as point sources. Astrometric measures of the positions of asteroids taken from photographs of the image orthicon monitor screen compared quite favorably with those obtained by conventional photographic means, particularly if the comparison stars measured were at the undistorted center of the screen.

The apparition of Comet Kohoutek in late 1973 and early 1974 was given special attention. In view of the great expectations concerning this comet, the

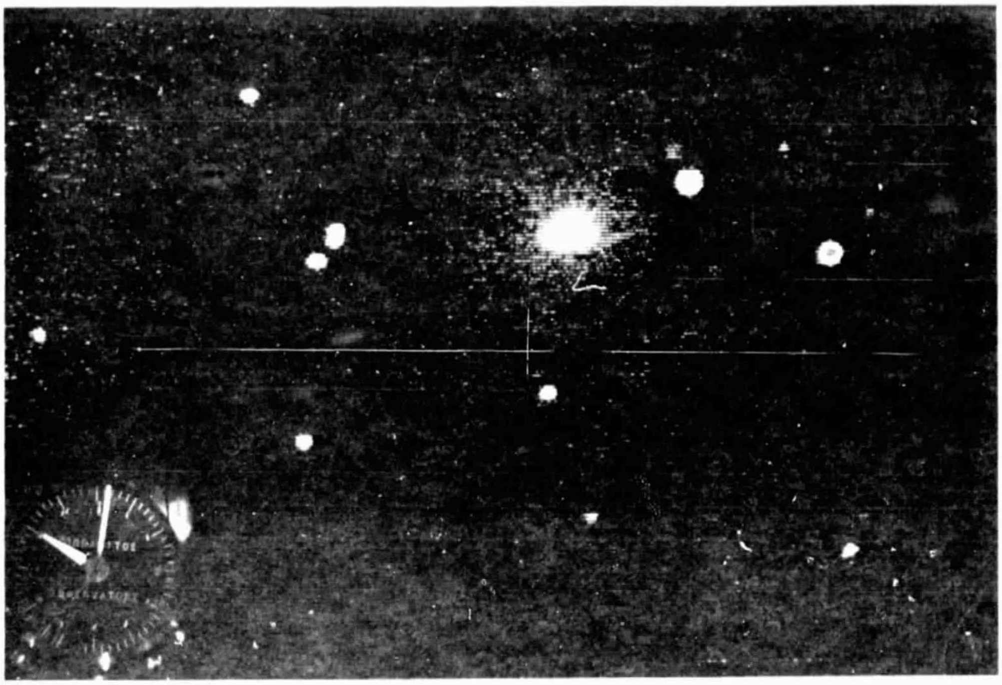

Figure A-2. *New General Catalog* (NGC) 5055 without supernova with the orthicon system.

Figure A-3. NGC 5055 with supernova with the orthicon system.

Table A-1.–*Supernovae Discovered at the Corralitos Observatory*

Galaxy	Date	Magnitude	Magnitude of galaxy[a]	Offset from nucleus	Revised galactic classification[b]	IAU announcement card
NGC 6946	Feb. 6, 1968	15.4	11.1	45" E, 20" N	S (RS)	2057
NGC 4183	Oct. 29, 1968	14.5	12.6	20" W, 95" N	Sa	2109
NGC 1058[c]	Dec. 2, 1969	13.5	12.7	190" E, 125" S	Sa	2195
IC 3476	Feb. 26, 1970	14.2	13.7	–	S	–
NGC 3904	Jan. 31, 1971	15.3	11.9	167" W, 60" S	E	2305
Anonymous	Feb. 22, 1971	19.5	–	16" W, 5" N	S	2309
NGC 5861	Feb. 24, 1971	15.5	12.4	33" E, 2" N	Sab	2309
NGC 5055	May 24, 1971	11.8	10.5	2" W, 147" S	Sa	2330
NGC 6384	June 24, 1971	13.0	12.7	27" E, 20" N	Sa	2336
NGC 3147	Jan. 10, 1972	15.5	11.9	335" W, 120" N	Sa	2381

IAU = International Astronomical Union; NGC = *New General Catalog*; IC = *Index Catalog.*
[a]Apparent photographic magnitude taken from the *Reference Catalog of Bright Galaxies* (de Vaucouleurs, 1864).
[b]Taken from the *Reference Catalog of Bright Galaxies* (de Vaucouleurs, 1864).
[c]Independent co-discovery.

Corralitos Observatory had planned to study very-short-term tail structure variations, but when the comet did not become as bright as had been optimistically predicted, observing plans were changed somewhat. The observatory staff obtained many image orthicon observations on the comet nightly in January 1974. A typical observation is shown in figure A-7. It should be noted that for this photograph a 5-in. objective lens was mounted in connection with the image orthicon in the 24-in. telescope to increase the field covered. Even so, only part of the comet appears in the photograph as the tail extended a great distance. Figure A-8 illustrates a unique view of the comet against the horizon lights of Deming, N. Mex., some 50 miles to the west of the Observatory. A photograph of this sort would be impossible by any means except an image orthicon system. It was demonstrated that the image orthicon is useful in cometary applications.

Under the sponsorship of the Air Force, a project was undertaken to prove the validity of the image orthicon as a photometric device of acceptable accuracy. Using the image orthicon electro-optical system, attached to the 24-in. telescope and cooled to 10°C, the galactic star cluster NGC 188 was examined in the range 9.0 to 19.0 visual magnitude. The readout on the monitor screen was photographed with a Hasselblad camera, and the diameters of the resulting stellar images were measured. In this application it was found that the linear diameter of the images is directly proportional to the magnitude of the object in integrated light over a range of some nine magnitudes (representing a brightness range of over 4000). Acceptable accuracies of 5 percent are attainable, which is essentially the same as those given by photographic photometry. The method can be used for calibration of fainter stars, of as yet undetermined magnitudes, in terms of brighter known objects and promises to be extremely valuable since accurate magnitude determinations for stars as faint as the 17th and 18th magnitudes are available for very few stars. A separate report will be issued soon concerning this project.

Finally, the application of the image orthicon in unusual tracking and detection situations is illustrated by figure A-9, which shows two unidentified synchronous satellites, which appear as point sources while the stars are visible as trails. Obtaining a photograph of approximately 16th-magnitude objects such as these would be difficult indeed without an orthicon-based system.

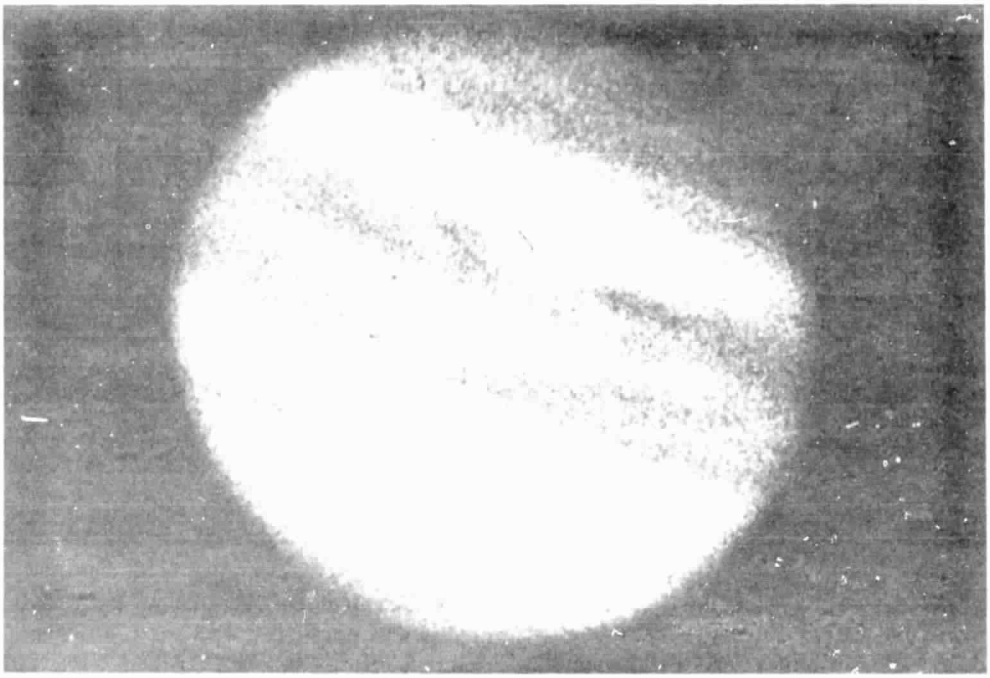

Figure A-4. Jupiter with the orthicon system.

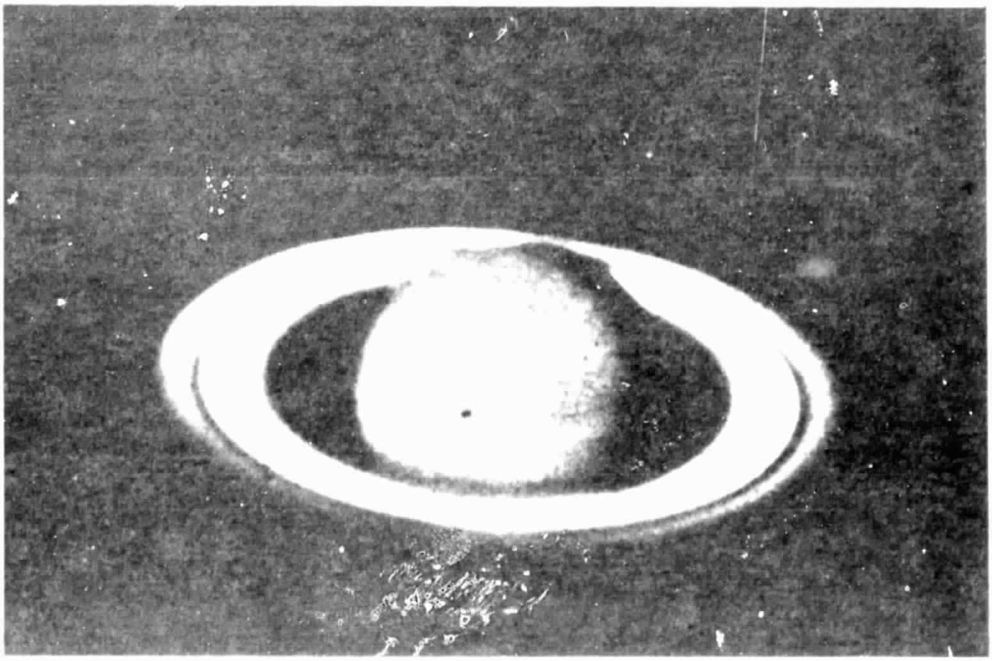

Figure A-5. Saturn with the orthicon system.

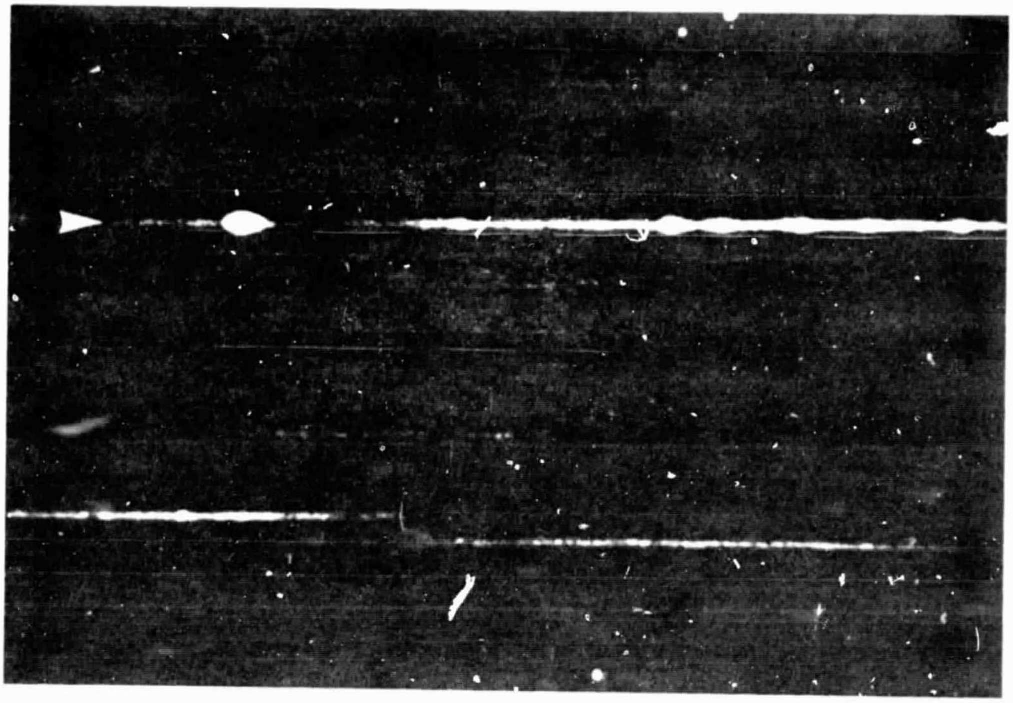

Figure A-6. Nonobjective spectrum of the planetary nebula BD+30° 3639; 3/8th-s integration time.

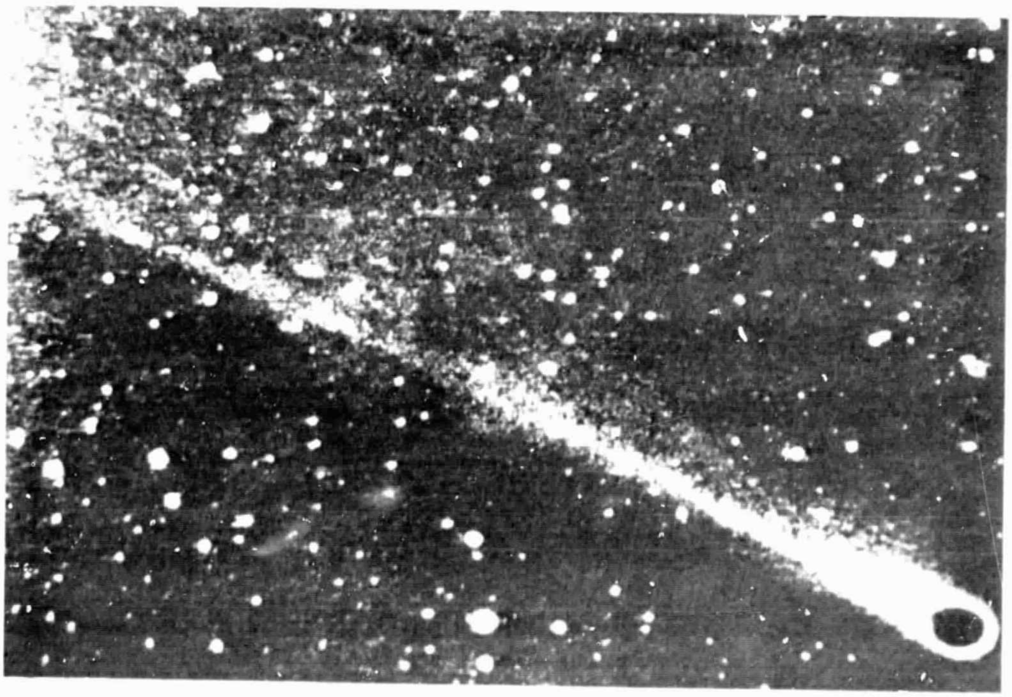

Figure A-7. Head and portion of the tail of Comet Kohoutek as seen with the orthicon used in conjunction with a 5-in. objective lens.

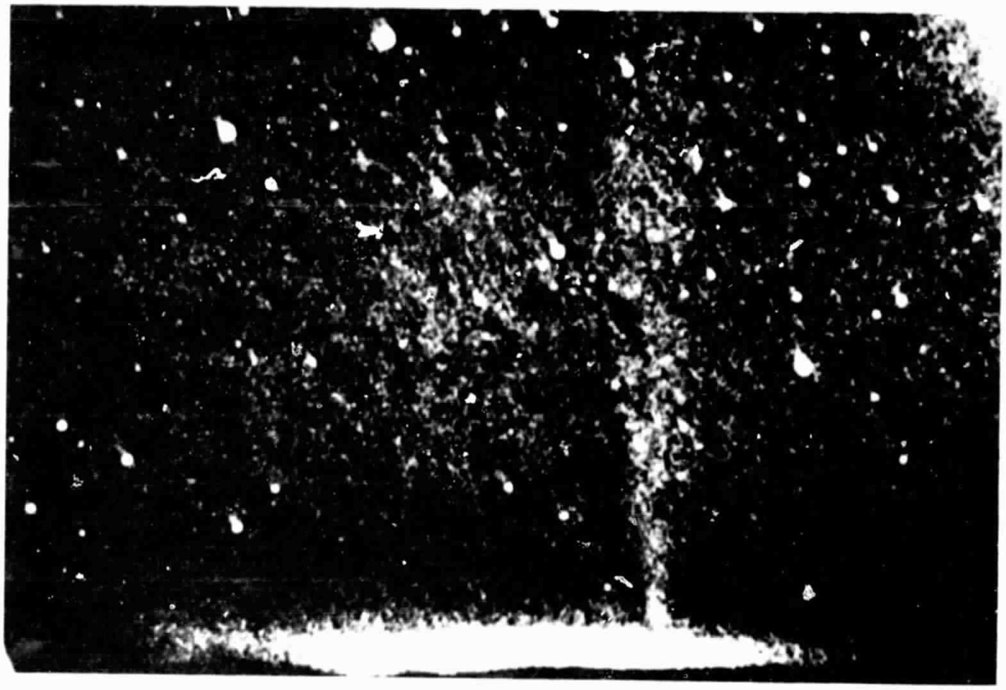

Figure A-8. Comet Kohoutek seen setting in the horizon lights of Deming, N. Mex., as seen with the orthicon used in conjunction with a 5-in. objective lens.

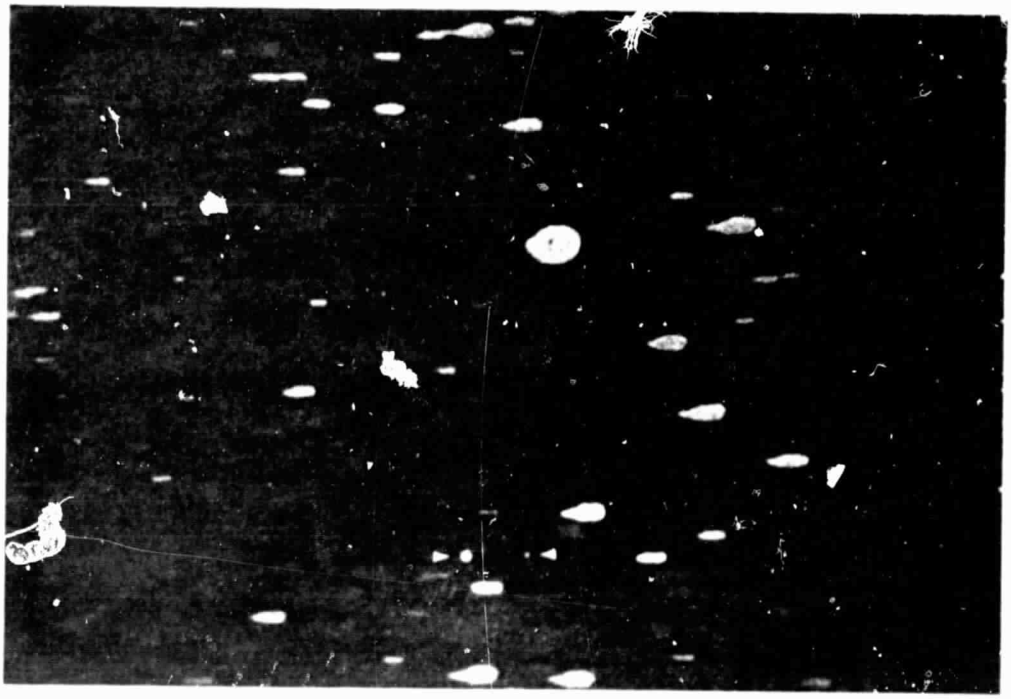

Figure A-9. Two unidentified synchronous satellites, integration time 2 s.

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