NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

LUNAR CARTOGRAPHIC DOSSIER

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ORIGINAL CONTAINS COLOR ILLUSTRATIONS

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FOREWORD

THROUGHOUT MAN'S HISTORY on earth he has sought to explore the outer reaches of his environment and to map his findings. His first cartographic efforts have recorded the minimal topographic information necessary to insure group survival and cartographic progress has gradually developed in conjunction with increased ability to function in new regions. His earthbased view of the moon similarly progressed from the fanciful to an ordered science limited only by earth-moon distance and geometric relationship.

In less than a decade, lunar exploration and corollary mapping have progressed to the vantage point of lunar proximity, thereby yielding the first description of the lunar farside and enabling man's personal exploration of the moon's surface.

This book is concerned with recording the cartographic results and by-products of lunar exploration and study. It is an attempt to provide a vehicle for the continued accumulation and use of lunar cartographic knowledge.

February 1973

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PREFACE

THE LUNAR CARTOGRAPHIC DOSSIER is designed to provide an up to date summary of the extent and quality of cartographic information as well as describing materials available to support lunar scientific investigation and study. Its basic informational sections. Photography (Sec. 2.0), Control (Sec. 3.0), and Maps (Sec 4.0) cover the specific photographic, selenodetic and cartographic data considered to be of continuing significance to users of lunar cartographic information. The Development of Lunar Cartography (Sec. 1.0) presents historical background data.

The Map Section includes descriptive and evaluative information concerning lunar maps, photomaps and photo mosaics. Discussion comprises identification of series or individual sheet characteristics, control basis, source materials and compilation methodology used.

The Control Section describes the global, regional and local selenodetic control systems that have been produced for lunar feature location in support of lunar mapping or positional study. Further discussion covers the fundamental basis for each control system, number of points produced, techniques employed and evaluated accuracy.

Although lunar photography is an informational source rather than a cartographic product, a Photography Section has been included to facilitate correlation to the mapping and control works described. Description of lunar photographic systems, photography and Photo Support Data are presented from a cartographic-photogrammetric viewpoint with commentary on cartographic applications.

Photo, Map and Control Indices follow each of the basic Dossier Sections, providing lunar locations for data and materials discussed. Each category of index is keyed to a common base enabling ready relation of varying combinations of photo, map and control data.

By its summary nature, the Dossier is limited in both narrative and graphic detail. Reference Sections identify documentation available for more intensive study of specific projects. In the case of photography, reference is made to larger scale indices for identification and location of individual photographs.

Evaluative information contained, primarily reflects accuracy data derived by producing agency at time of product publication. Modification of original evaluation is sometimes offered, based upon the further experience of Dossier's editorial staff and contributors. The Dossier's looseleaf form lends itself to updating of lunar cartographic knowledges and contributions from product users are invited. Such contributions should be directed to:

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February 1973

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The compilation of this summary of lunar cartographic work has primarily depended upon the efforts of personnel of the United States Defense Mapping Agency Aerospace Center. Particularly valuable were the contributions of Robert Carder and Raymond Anderson to Lunar Map Subjects; Donald Meyer, Charles Ross, William Cannell, and Lawrence Doepke to Selenodesy and Control Works; and, Richard Palm and Lawrence Klages to photographic subjects. Mr. Ewen Whitaker, Lunar and Planetary Laboratory, University of Arizona, furnished considerable assistance in development of "History of Lunar Mapping."

The editor is also indebted to personnel of the Defense Mapping Agency's Topographic Center and the National Aeronautics and Space Administration Apollo Exploration Office and Mapping Sciences Branch for contributions and suggestions provided.

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The continuing contribution to lunar mapping and control subjects by Messrs. Charles Shull and James Stephens, Defense Mapping Agency Topographic Center, is most appreciated.

Updating of Dossier discussion of lunar nomenclature has been accomplished through the assistance of Dr. Farouk-El-Baz, Smithsonian Institution.

LAWRENCE A. SCHIMERMAN
Editor

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DEVELOPMENT OF LUNAR CARTOGRAPHY 1.0

This Section is concerned with historical and background information to enable a better appreciation for modern cartographic and selenodetic products described in Sections 3.0 and 4.0.

History of Selenodesy 1.1

History of Lunar Mapping 1.2

Lunar Nomenclature 1.3

HISTORY OF SELENODESY
1.1

One might say that selenodesy began when man first realized that the moon is spherical. Aristotle (384-322 B.C.) was the man who deduced the shape of the moon from his observations of eclipses and changing lunar phases. He was also able to deduce from these observations that the moon is closer to the earth than the sun and the planets, and that it shines by reflected light from the sun.

The deductions of Aristotle caused Aristarchus (320-250 B.C.) to devise a method of making the first measurements of the relative distances of the moon and sun from the earth. He found the distance to the moon to be 56 earth radii and the solar distance to be 20 times the moon's distance. His lunar distance was in error by only seven percent, but his solar distance was in error by a factor of 20.

Another Greek astronomer, Hipparchus (circa 160-120 B.C.) made precise observations which advanced the theory of the moon's motion to a relatively high level. He discovered that the lunar motion relative to the earth was not exactly circular. Without the formulation of the law of gravitation, he assumed that the eccentricity of motion was caused by the earth being situated eccentrically rather than in the exact center of the moon's probable circular orbit. Hipparchus also measured, with amazing accuracy, the inclination of the lunar orbit to be 5° to the plane of the earth's orbit around the sun and the period of the revolution of the line of nodes to be 18⅔ years. Hipparchus was the first to realize the existence of lunar parallax and from it he determined the moon's distance to be 59 earth radii and its diameter to be 31 minutes. This was remarkably close to telescopic accuracy.

Ptolemy (100-170 A.D.) went beyond Hipparchus in the accuracy of his determinations of orbital constants, but his measurements of the lunar distance and diameter were not very accurate. Most of the error resulted from his use of the too small radius of the earth determined by Posidonius. After Ptolemy, our search for knowledge of the moon rested and the pause lasted for nearly 14 centuries.

It was primarily the works of Brahe, Kepler, Galileo and Newton which broke the scientific lull and lifted mankind from the Dark Ages. Tycho Brahe's (1546-1601) prime contribution was the gathering of large amounts of observational data which proved to be vital to Kepler (1571-1630) in perceiving the three laws of planetary motion. Galileo (1564-1642) was the first to apply the telescope to lunar studies and with his "optic tube" made eyeball sketches of the lunar surface which revealed to him the moon's libration in latitude. Galileo also made the first crude attempt to measure lunar heights by estimating the distances beyond the terminator at which some high peaks were barely illuminated.

Kepler's three laws of planetary motion were strictly empirical deductions from Tycho's data, but Newton (1642-1727) was able to explain them as natural consequences of his equally famous three laws of motion and the law of gravitation. In the *Principia*, 1687, Newton discussed the applications of the law of gravitation and the laws of motion to the earth-moon system. He demonstrated that the earth's gravitational pull would elongate the surface of a simple lunar model toward the earth by 186 feet. In this way, Newton explained the sameness of the lunar day and month as a result of a tidal couple which would automatically keep the bulge closely aligned with the line connecting the centers of the earth and moon.

In 1693, the Italian astronomer Cassini (1625-1712) announced his three empirical laws of lunar rotation:

1. The moon rotates uniformly about its axis of rotation with a period equal to its sidereal period of revolution around the earth.

2. The inclination of the moon's equator to the ecliptic remains constant.

3. The ascending node of the moon's equator on the ecliptic coincides always with the descending node of the lunar orbit on the ecliptic.

These laws later led Lagrange, Laplace and Poisson to make a series of investigations into the dynamics of lunar rotation.

The first careful triangulation of features on the lunar surface was made in 1748 by the young German astronomer, Tobias Mayer (1723-1762). Using measures he obtained with a glass micrometer, Mayer determined the position of Manilius (selected as the fundamental crater near the center of the moon) to be $+9°2'$ in selenographic longitude and $+14°34'$ in selenographic latitude. He also found the inclination of the lunar equator to the ecliptic to be $1°29'$. He micrometrically measured 23 more points and estimated the positions of 65 other points referenced to those derived micrometrically to establish the first selenodetic control system. Mayer proceeded to map the moon with the greatest possible precision and produced two full moon maps but neither was published during his lifetime. In 1752, he published a lunar ephemeris and a table of lunar distances which were accurate enough to determine longitude at sea to within one degree.

In 1764, Joseph Lagrange (1736-1813), a French mathematician, demonstrated from dynamic principles that the moon must have an ellipsoid shape whose polar axis should be depressed by about one-third of the excess of its major axis over the mean. He also proved that the earth's attraction on the moon would have sufficed to force the moon always to present one face toward the earth even if it had not done so originally. In 1780, he developed the equations describing the physical librations of the moon which were confirmed seven years later by Laplace and extended still later in 1818 by Simon Poisson (1781-1840).

The existence of physical libration had been clearly demonstrated in theory, but the actual observations of it were very difficult because the quantities involved are extremely small. Observations to detect such small quantities were undertaken in 1806 by Alexis Bouvard (1767-1843) and Dominique Arago (1786-1853) who determined the position of the crater Manilius from a series of 18 measures. This project was repeated and extended by Bouvard's new measures between 1816 and 1818, and he announced that he had found the physical libration in longitude to be 4 minutes and 46.0 seconds. Following this Nicollet made 32 measures of the same crater and by combining the 174 available measures he arrived at the maximum value of 4 minutes 49.7 seconds for the real libration in longitude.

From 1822 to 1826, the German selenographer Wilhelm Lohrmann (1796-1840) measured the selenographic positions of 79 points with a filar micrometer in an effort to provide an accurate base for the lunar map he was constructing. He measured each point from the limb of the moon 2 to 12 times and calculated the positions according to the formulae developed by Johann Encke (1791-1865). His map was not published during his lifetime, but it represented the beginning of highly detailed scientific lunar mapping.

While Lohrmann was still occupied with his lunar map, a similar project was being conducted in Berlin by Wilhelm Beer (1797-1840) and Johann Mädler (1794-1874). Mädler used a four-inch refractor in Beer's rooftop observatory to measure the positions of 106 lunar features with a filar micrometer. Connecting these points into 176 fundamental triangles, he provided the control net for their map. Mädler derived a great number of secondary positions from the fundamental triangulation and he also measured the heights of 800 individual peaks. He further derived the heights of additional elevations by comparing their shadows with those measured micrometrically. He also measured the diameters of 150 craters and estimated the size of numerous others by comparison. His results appeared in *The Moon or General Comparative Selenography*, a book which contained a complete analysis of the methods used and detailed accounts of all measurements. The work of Mädler represented the highest achievement in the selenodesy of the 19th century.

Mädler had experienced the observational problem of determing the physical libration of the moon when using Manilius as the fundamental crater. This led him to express the need for a better fundamental crater located closer to the center of the disk. Bessel (1784-1846) suggested the small bright crater Mösting A, on the slopes of Flammarion, to which Mädler responded by starting a series of measures on Mösting A using the small heliometer of the Berlin Observatory. Mädler never finished this project but in 1839 Bessel himself determined the position of Mösting A from two sets of measurements made with the 6.25-inch heliometer of the Königsberg Observatory. Between 1844 and 1846, Schlüter (a student of Bessel's) made a series of 50 measures on Mösting A using the Königsberg heliometer and concluded that the physical libration could not exceed ten minutes in selenographic longitude. Mösting A thus became established as the new fundamental crater for selenographic measures.

Introduction of the heliometer at Königsberg in the 1840's led E. Hartwig (1851-1923) to conduct three series of observations to determine the constants of physical libration. The first was the Strassburg series (1877-1879), consisting of 42 evenings of observations which were reduced by Hartwig himself. The second was the Dorpat series (1884-1885), consisting of 36 evenings and reduced later by the Polish astronomer, K. Koziel in 1948-49. The third of his series was made in Bamberg(1890-1922) and reduced in part by Naumann in 1939.

Julius Franz (1847-1913) began selenodetic work at the Königsberg Observatory in 1885. Using Schlüter's Königsberg heliometer series for Mösting A, he first derived the libration constants of the moon, namely the selenocentric longitude and latitude of Mösting A, its distance from the moon's center, and the inclination of the lunar equator to the ecliptic. He also determined the selenographic coordinates of Aristarchus, Byrgius A, Fabricius K, Gassendi Z (now Gassendi ζ), Macrobius A, Nicolai A, Proclus, and Sharp A to establish a system of nine fundamental reference points. His reductions proved to be more accurate than those derived by Mädler and Beer, who measured their control points with a hairline micrometer. Thus, the heliometer was established as a high accuracy micrometer for lunar measures.

With the exception of Pritchard's determination of Mösting A (at Oxford), Franz was the first to take advantage of the photographic plate to efficiently extend selenodetic work. Programs to photograph the moon had just started in the 1890's at the Lick Observatory with the 36-inch refractor and at the Paris Observatory with the 24-inch Coudé refractor. In 1899, Franz measured five of the Lick Observatory plates taken around 1890. From these measures, and in conjunction with his nine basic heliometer positions, he derived 150 selenographic positions and the absolute heights of 55 craters; with this information, he constructed the first contour map of the moon. He also derived a value for the lunar bulge which he found to be 6,500 feet ± 2,200 feet - - about twice the value determined from dynamic principles. This reduction was unfortunately defective in that his libration theory was in error. His contour map indicated that the "continents" of the SE (astronautical) quadrant are relatively higher than those in the NW quadrant. He later made additional measures on these plates totaling 1,300 points in all. His later measures were added for cartographic purposes only and did not have the precision of the first 150. The errors of his best points were about one minute of arc (selenocentric). All were derived from the position of Mösting A and the rotation constants determined from the heliometer measures observed and reduced by Franz himself.

In 1911, S. A. Saunder (1852-1912) in England published his catalog of 2,885 points which he measured on four Paris Observatory plates and two Yerkes plates. Saunder combined his measures with the 1,300 measures by Franz and allowing for common points, the total measures of these two men reached 3,500 points. These combined measures provided the best cartographic control network for many years. Saunder also made a deliberate attempt to determine the eccentricity of the prime meridian. For this purpose he used 38 points from his Paris measures which were close to the central meridian. From these 38 points, he derived a bulge of 3,000 ± 1,550 feet. Upon removing two points farthest north, he found that his results were very similar to those of Franz.

Friedrich Hayn (1863-1928) made micrometer measures of the coordinates of Mösting A, Egede A, Kepler A, Messier A, and Tycho with the 12-inch refractor at Leipzig from 1904 to 1914. He reexamined the entire theory of physical libration, improving the constants derived by Franz and introducing the mechanical ellipticity as an unknown. His theory overcame some of the defects in the theory Franz used, but it led to ambiguity in some of the small periodic terms.

Heliometer measures were carried out extensively at the Engelhardt Observatory, Kazan, USSR, starting in 1895. The first of the Engelhardt series began with Krasnov (1895-98) and Mikhailovski (1898-1905). Banachiewicz (1882-1954) made the second of the series of heliometer measures (1910-1915) which was reduced by Jakovkin in 1928. Jakovkin made the third (1916-1931), Belkovich the fourth (1932-1942) and Nefedyev the fifth (1938-1945). All of these observations were reduced to obtain the constants of physical libration and the position of Mösting A. In these reductions, however, two aspects of the problem were disregarded: errors in the mean longitude of the moon, and the nonlinearity between the unknown mechanical ellipticity and the observed quantities. The first error arose from the fact that up to 1882 the *Nautical Almanac* used Hansen's tables for the ephemerides of the moon, and considerable deviations were appearing from the given place. In 1883, Newcomb (1835-1909) made some corrections to Hansen's lunar theory but not to the mean longitude of the moon. In 1923, Brown's theory was adopted and the moon's mean longitude was corrected.

For the lack of better procedures, a further error was caused by continuing to apply the conventional least squares form of adjustment computations. The Austrian astronomer Schrütka-Rechtenstamm and Koziel noted that a discontinuity in the physical libration in longitude existed near the critical value of about 0.66 in the mechanical ellipticity. In his physical libration investigations of 1955, Schrütka provided an artifice which consisted of taking two unknowns instead of one and combining them in such a way as to avoid the discontinuity in the vicinity of the singular point.

From the thousands of heliometer measures of Mösting A, obtained by the dedicated observers over the previous 120 years, many independent as well as collective reductions were performed in the 1950's and early 1960's to derive the basic libration constants of the moon. Koziel used the modern electronic computer to combine all available observations into one adjustment to arrive at a best set of physical libration values. In 1963, Koziel reported that he had determined a set of physical libration constants by using a total of 3,282 observations out of four series of measures. The series used were: the Strassburg series (1877-1879), the Dorpat series (1884-1885), the first half of the Bamberg series (1890-1912), and the Kazan series (1910-1915). The outstanding result of the study was that the value found for the mechanical ellipticity was on the lower side of the critical value of 0.66.

Koziel's libration constants were published as follows:

$$\lambda \text{ (Mösting A)} = -5°9'50'' \pm 4''.5$$
$$\beta \text{ (Mösting A)} = -3°10'47'' \pm 4''.4$$
$$h \text{ (Mösting A)} = 932''.98 \pm 0''.19$$
$$I = 1°32'01'' \pm 7''.1$$
$$f = 0.633 \pm 0.011$$

In the 1950's, Josef Hopmann (University of Vienna) and Schrütka-Rechtenstamm reworked the 150 photographic measures of Franz to derive new positions and feature heights with respect to a mean sphere. Their interest in the figure of the moon led to their publication of a contour map of the moon in 1958. In general, they found an earthward bulge on the order of 9,500 feet. The probable error for a single height from these measures was ±4,030 feet.

At the Yerkes Observatory in 1958, Messrs. Arthur, Whitaker, and Moore successfully adapted the 40-inch, f/19, visual refractor for selenodetic photography. In the spring of 1959, they began the Yerkes selenodetic photographic program. A number of exposures of the Pleiades were obtained at widely different temperatures for calibration of focal length. The lunar plates were star-trailed after each exposure which allowed orientation to be determined independent of heliometer measures. Avoiding all reference to the moon's rotation theory, it was then possible to approach the problem of lunar surface positions by photogrammetry alone.

In 1963, Ralph B. Baldwin (U.S. astronomer) published the results of his 696 measures from copies of five Lick Observatory plates. Fundamental control points for determining plate constants were the 150 points of Franz as reduced by Schrütka in 1958, and the libration constants and refraction corrections were those supplied by C. B. Watts of the United States Naval Observatory. Results of the reduction revealed that the probable error in a single height determination was ±2,270 feet, substantially less than that found by Schrütka. The derived heights for all 696 points were compiled into a contour map, which confirmed that the continents of the SE quadrant are higher than those of the NW quadrant as found by Franz over half a century earlier. Baldwin's map clearly reveals a positive lunar bulge generally aligned with the earth and larger than the dynamically determined value.

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HISTORY OF LUNAR MAPPING
1.2

The first map of the moon on record predates the invention of the telescope and was based on naked-eye observations. However, the history of lunar mapping parallels the history of the telescope with maps improving as telescopes of greater power came into use. Naturally, the earlier maps have the limitations of their times since the observers used small apertures and were unable to detect numerous features which can now be discerned with ease on lunar photographs.

The earlier lunar maps were drawn with north at the top just as modern lunar and terrestrial maps are drawn today. This was the custom in the early days of lunar mapping since the eyepiece in the first telescopes produced an image right side up. Later, more efficient telescopes were constructed with an eyepiece which produced an inverted image. Thus, many of the follow-on observers produced lunar maps with south at the top, the same as viewed in the telescope.

Following is a chronological history of lunar mapping, illustrated in many instances with a reproduction of the crater Copernicus copied from the lunar map of a particular observer. At the outset it should be emphasized that a fair comparison between these individual drawings can be made only by taking into consideration the lunar diameter at which the originals were drawn. For ease of interpretation all illustrations have been oriented with north at the top.

circa 1600–GILBERT

William Gilbert (British scientist, 1540-1603, the discoverer of terrestrial magnetism)

Galileo is normally credited with drawing the first map of the moon but in Gilbert's book "De Mundo Nostro Sublunari, etc." he includes a map of the moon, Figure 1. This map, based on naked-eye observations, was made some time prior to his death in 1603 which was some five years before the invention of the telescope. Without a telescope, Gilbert could only distinguish between the light and dark areas of the moon which he outlined on his map. Also, contrary to Galileo's interpretation, Gilbert believed the darker areas to be continents with the lighter areas being seas. The area that he named Regio Magna Orientalis (Great Eastern Region) bears a close resemblance to Mare Imbrium; the same is true for his "Britannia", which coincides quite well with the position of Mare Crisium.

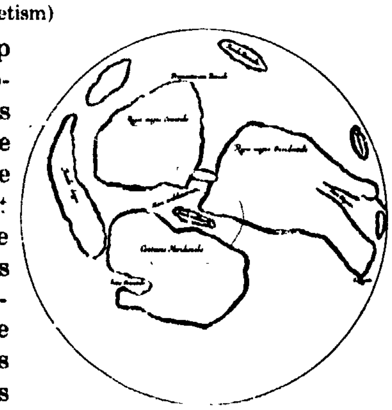

Fig. 1 Gilbert-circa 1600

1610 - GALILEO

Galileo Galilei (Italian astronomer, 1564-1642)

Galileo, known to history by his first name, was probably the first man to see the moon through a telescope. While Galileo is not credited with inventing the telescope, he did combine two lenses into a "seeing tube," and on a clear night in June 1609 turned his crude instrument toward the moon. Thus, he was able to distinguish for the first time what appeared to be craters, mountains and seas on the lunar surface. The following year Galileo published his discoveries in a book entitled "Sidereus Nuncius" which contained four different phase sketches of the moon, each drawn 8 cm (3.14 inches) in diameter. Actually, his book contains five lunar drawings but one was duplicated on another page.Two of Galileo's original lunar drawings, copied from his "Sidereus Nuncius," are shown in Figures 2 and 3.(North is at the top.) An interesting fact is that there are other sets of Galileo moon maps in print reported to be from his book but in reality these are substandard copies drawn by other artists.

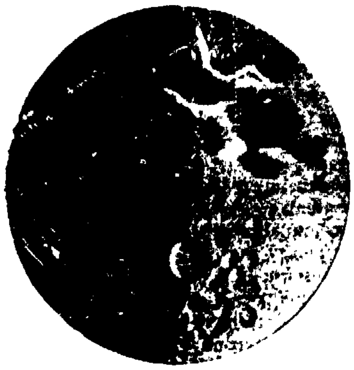

Fig. 2 Galileo-1610

Fig. 3 Galileo-1610

1610 - HARRIOT

Thomas Harriot (British mathematician, 1560-1621)

About the same time Galileo was observing in Italy, Harriot in England commenced his observations of the moon with a x6 telescope. On September 12 and 13, 1610, he drew two waxing moons which clearly show the feature Mare Crisium and what appear to be outlines of Mare Tranquillitatis, Nectaris and Fecunditatis. Probably during the same time he drew the full moon map shown in Figure 4. This map was made by carefully noting alignments of features and relative distances between them. The accuracy of his map becomes apparent by a visual comparison with the full moon photograph shown in Figure 5.

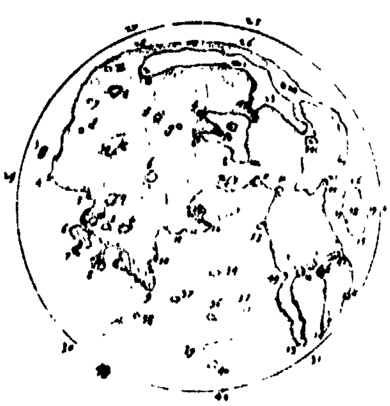

Fig. 4 Harriot-1610

Fig. 5 Pic du Midi
Full Moon Photo

1614 - SCHEINER

Christopher Scheiner (German Jesuit astronomer, 1575-1650)

Fig. 6 Schein r-1614

Galileo and Harriot by no means had a monopoly on telescopes since about the same time Scheiner in Germany had obtained one. In fact, by 1611 he owned at least eight of these scarce instruments. Scheiner's lunar map, Figure 6, published in 1614, shows a first-quarter moon oriented with north at the top. In some respects, Scheiner's map indicates more detail than Harriot's. Many features designated by letters (names for lunar features were not introduced until 1645 by Langrenus) can be identified by reference to the full moon photograph in Figure 5. Thus A is Mare Crisium; B, Mare Spumans; C, Mare Frigoris; D, Mare Serenitatis; E, Mare Tranquillitatis; F, Mare Fecunditatis; G, Mare Nectaris; and M, the crater Aristoteles. The area to the south along the terminator, as drawn by hachures, represents the southern highlands.

1619 - MALAPERT

Charles Malapert (Belgian Jesuit philosopher and astronomer, 1581-1630)

Following the works of Harriot and Scheiner, Malapert in 1619 produced a phase sketch of the moon drawn 4.9 cm (1.9 inches) in diameter. His sketch showed the moon in two forms, one with north at the top and one with south at the top, the same as observed through ar inverted image telescope.

Fig. 7 Mellan-1637

1637 - GASSENDI/MELLAN

Pierre Gassendi (French astronomer, 1592-1655)

Claude Mellan (French engraver, 1598-1688)

From observations by Gassendi and his friend, Nicolas Claude Fabri de Peiresc (1580-1637), Mellan produced three very fine engravings of the moon during 1634-35. His engravings, 21 cm (8.3 inches) in diameter, consisted of a waxing gibbous, a full moon, and a waning gibbous, all oriented with north at the top. These engravings, both in accuracy and artistic appearance, surpassed all previous attempts to draw the lunar surface. Mellan's engraving of the crater Copernicus is shown in Figure 7.

1645 - LANGRENUS

Michel Florent van Langren (Langrenus, Belgian engineer and mathematician, 1600-1675)

Langrenus' map, published in 1645, was the first to assign names to lunar features, these being named after geographical locations, scientists, noblemen and crowned heads. He named the crater Copernicus after Philip IV (King of Spain from 1621 to 1665). Over sixty of Langrenus' names survived the passage of time but only four in their original locations: the craters Langrenus (after himself), Endymion, and Pythagoras plus Sinus Medius, later renamed Sinus Medii. The crater Copernicus, Figure 8, was copied from Langrenus' map, 33.6 cm (13.2 inches) in diameter, and was oriented with north at the top. His map is simply drawn with shaded outlines for craters and a stipple for the maria.

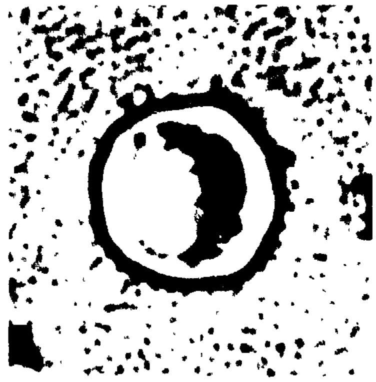

Fig 8 Langrenus-1645

1645 - RHEITA

Anton Maria Schyrle of Rheita (Czech Capuchin monk and optician, 1597-1660)

Also in 1645, Rheita published the first lunar map oriented with south at the top, based on telescopic observations with an inverting eyepiece that he designed. Rheita's map, 18.5 cm (7.3 inches) in diameter, shows a fairly accurate delineation of the maria which are shaded with parallel lines spaced close together to give a dark appearance. The larger craters, some with their ray structures, are indicated in their respective locations, but for the remainder of his map Rheita filled in the cratered areas with symbolic detail. His map contains no nomenclature but, like Scheiner, he used letters to designate major features. Shown in Figure 9 is Rheita's drawing of the crater Copernicus.

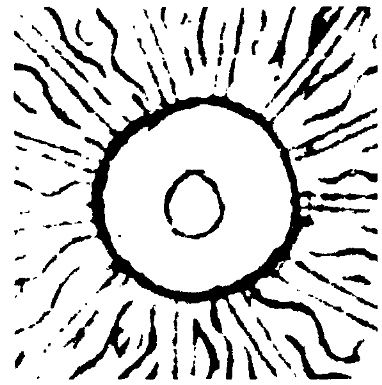

Fig. 9 Rheita-1645

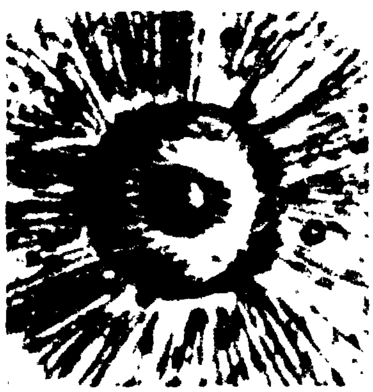

Fig. 10 Fontana-1646

1646 - FONTANA

Francesco Fontana (Italian lawyer and amateur astronomer, 1585-1656)

Fontana's map, published in 1647 and oriented with south at the top, was an abortive attempt to draw the moon and must be considered substandard to other lunar maps of that time. Fontana paid little attention to either position or detail and, except for some of the major features, he symbolized areas outside of the maria more or less by drawing craters at random. His map did not carry any nomenclature. Fontana's drawing of Copernicus, copied from his 24 cm (9.44 inches) diameter map, is shown in Figure 10.

1647 - HEVELIUS

John Hewelcke or Hevel (Hevelius) (Polish astronomer, 1611-1687)

By 1647 Hevelius had accomplished sufficient work at the telescope to publish three lunar maps, each 28 cm (11 inches) in diameter, plus 40 drawings of individual phases of the moon. His full moon drawings, all oriented with north at the top, showed for the first time the maximum libration of the limb regions. From one of Hevelius' maps, the crater Copernicus is shown in Figure 11. This map was drawn with a series of parallel lines of varying thickness – a very effective technique for portraying lunar features at the scale at which the original was made. Hevelius disregarded the nomenclature introduced by Langrenus, and devised a system of names based on terrestrial counterparts. Accordingly, he gave the names of Alps, Carpathians, Caucasus, Apennines, and so on, but few of his proposed names survived. Incidentally, he named Copernicus, Mt. Etna, and the surrounding area, Sicilia.

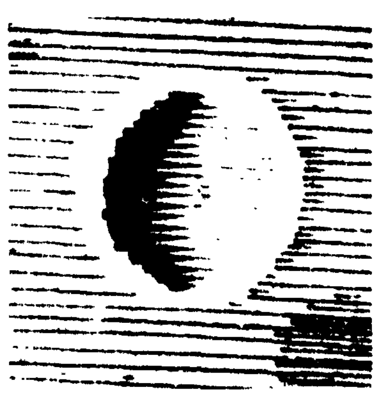

Fig. 11 Hevelius-1647

1649 - DIVINI
Eustachio Divini (Italian telescope maker, 1610-1685)

Following Hevelius, the next map to emerge on the lunar scene was one in 1649 by Divini. His map, while copied from Hevelius' maps, does not appear to be as accurately or as precisely drawn as the maps of Hevelius. One noticeable feature on Divini's map is the extensive ray systems of the craters Tycho, Copernicus and Kepler. Shown in Figure 12 is the Copernicus area from Divini's map engraved with a diameter of 28.8 cm (11.33 inches).

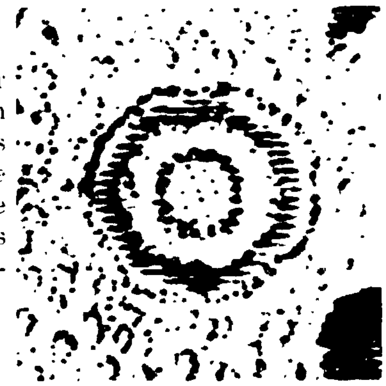

Fig 12 Divini-1649

1651 - RICCIOLI/GRIMALDI
Joannes Baptista Riccioli (Italian Jesuit astronomer, 1598-1671)
Francesco Maria Grimaldi (Italian Jesuit astronomer, 1613-1663)

Riccioli in 1651 published two maps, each 28 cm (11 inches) in diameter, oriented with north at the top and drawn by his student Grimaldi. Riccioli can be considered as the father of the lunar nomenclature system as we know it today; he was the one who discarded the names of Hevelius and named the craters after famous scientists or philosophers. He named the three rayed craters Aristarchus, Kepler and Copernicus after men who believed that the sun, and not the earth, was at the center of the universe. Riccioli believed that the earth was the center of the universe. So did the noted Danish astronomer Tycho Brahe, and for this reason Riccioli assigned the name Tycho to the most prominent of all rayed lunar craters. For the dark areas Riccioli gave exotic and picturesque names such as Mare Imbrium (Sea of Rains), Oceanus Procellarum (Ocean of Storms), Mare Serenitatis (Sea of Serenity) and many others which have remained in use to this day. In all, Riccioli proposed about 200 names. The Copernicus section of Riccioli's map is shown in Figure 13.

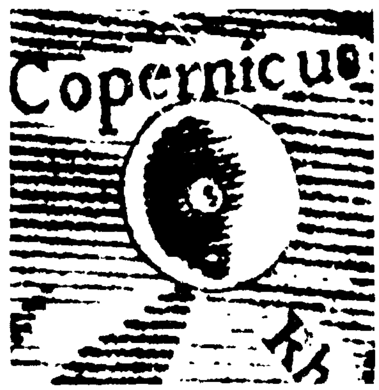

Fig. 13 Riccioli-1651

1662 - MONTANARI
Geminiano Montanari (Italian lawyer and astronomer, 1633-1687)

Montanari, the discoverer of the light changes of Algol (a star in the constellation Perseus), drew a map of the moon in 1662. His map, 38 cm (15 inches) in diameter on the original, was oriented with north at the top and did not include names. A review of Montanari's drawing reveals that it is inferior to all but Fontana's map but contains some features not shown in earlier maps. Montanari's drawing of Copernicus, shown in Figure 14, was copied from his lunar map.

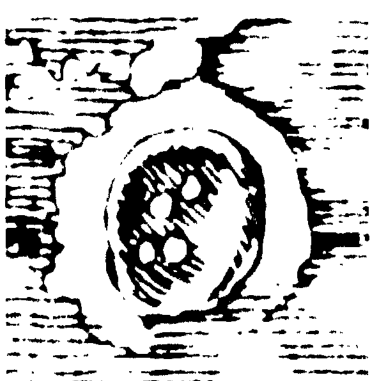

Fig. 14 Montanari- 1662

1680 - CASSINI

Giovanni Domenico Cassini (Italian astronomer, 1625-1712)

Cassini, recognized for his basic laws of the moon's rotation, drew a 54-cm (21.2-inch) diameter lunar map in 1680. His map, engraved by Claude Mellan, was the largest to be drawn as of this date. It revealed more detail than any of its predecessors, but in some areas Cassini drew small craters which did not exist. For example, Figure 15 from Cassini's map shows nonexistent small craters surrounding Copernicus. Cassini was the first to draw the area of Mare Smythii in the limb region. His map, oriented with south at the top, did not carry any nomenclature.

Fig. 15 Cassini-1680

1694 - EIMMART

Georg Christoph Eimmart (German engraver and amateur astronomer, 1638-1705)

Eimmart in 1694 engraved and published a 28.1-cm (11-inch) diameter full-moon map. His map does not include nomenclature and is oriented with north at the top. The Copernicus section of Eimmart's map, portrayed at full illumination, is shown in Figure 16.

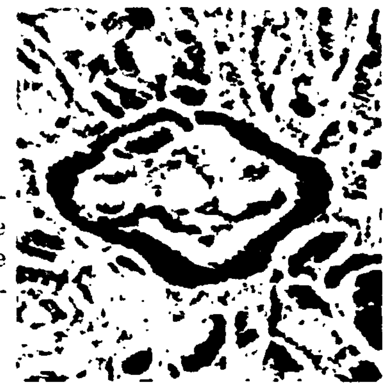

Fig. 16 Eimmart-1694

1764 - HELL

Maximilian Hell (Austrian Jesuit astronomer, 1720-1792)

Hell, born in Baňská Štiavnica, Czechoslovakia, entered the order of Jesuits and was well known as Father Hell. He became director of the Vienna Observatory and in 1764 published a full-moon map, 18.5 cm (7.3 inches) in diameter. His map, oriented with north at the top, does not show any names but instead carries numbers for many of the craters and letters for the maria and prominences. However, in the text that accompanies his map, there is a table of 130 formations with the names given by Riccioli and Hevelius. He added 11 of his own, of which 6 have been used again in different locations; the other 5 have been dropped. The Copernicus section from Hell's map is shown in Figure 17. From all appearances his map contributed very little, if anything, to the history of mapping the moon.

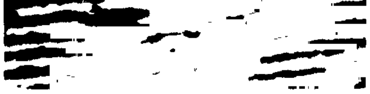

Fig. 17 Hell-1764

Fig. 18 Mayer–1881

1775 - MAYER

Johann Tobias Mayer (German astronomer, 1723-1762)

Mayer is considered by some as the first modern selenographer, for he was the first to establish a set of coordinates and draw a map of the moon based on carefully measured positions. In addition to being an astronomer, Mayer was a skilled mathematician and an accomplished cartographer, which perhaps accounts for the excellence with which he constructed his map. Mayer drew two complete maps of the moon, both similar in appearance, but neither was published during his lifetime. While the dates of his maps are hard to determine, it appears that they were drawn in the second half of 1750. His 19-cm (7.5-inch) diameter map, carefully shaded and oriented with north at the top, was published in 1775 by George Lichtenberg. A larger 46-cm (18-inch) map, similarly drawn but oriented with south at the top, was published more than a century later by Ernst Klinkerfues in 1881. A section of this map is shown in Figure 18. Neither of Mayer's maps carried any nomenclature.

1791 - SCHRÖTER

Johann Hieronymus Schröter (German selenographer, 1745-1816)

Schröter originally planned to construct a lunar map 118 cm (46.5 inches) in diameter but after nearly 30 years of observations he published in 1791 only isolated areas under the title "Selenotopographical Fragments." He continued with his lunar observations and published a second volume in 1802. Schröter's drawing of Copernicus, Figure 19, made in 1788 but not published until 1791, is indicative of his style of portraying lunar features. He used Riccioli's lunar nomenclature and added some 60 names. Schröter also introduced the system of identifying smaller features by the letters of the Roman and Greek alphabets. His drawings were oriented with south at the top.

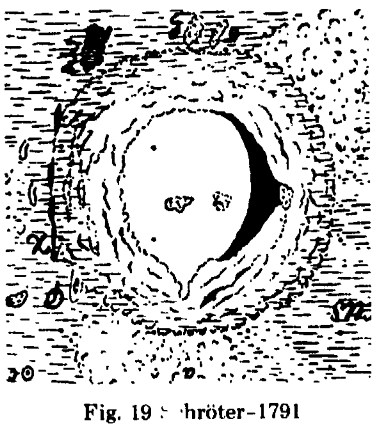

Fig. 19 Schröter-1791

1805 - RUSSELL

John Russell (English painter and amateur astronomer, 1745-1806)

Russell loved to observe the moon and over a period of years made a series of some 200 pencil sketches of various lunar formations. His map of the moon, about 38 cm (15 inches) in diameter on the original, was published in 1805. Shown in Figure 20 is Russell's drawing of the crater Copernicus. Also in 1797 Russell produced a 12-inch globe of the moon of which six copies are known to exist today.

Fig. 20 Russell-1805

1824 - LOHRMANN

Wilhelm Gotthelf Lohrmann (German selenographer, cartographer and surveyor of the Kingdom of Saxony, 1796-1840)

Lohrmann, observing with a 4.8-inch refractor, measured the selenographic positions of 79 points from 1822 to 1826. These measures provided the control for his lunar map of 25 sections having a diameter of 97.5 cm (38.4 inches). Four sections were published in 1824 and, while the remaining sections were compiled by 1836, they were not published during his lifetime. The remaining sections were later engraved and published in 1878 under the direction of Julius Schmidt. However, in 1838 Lohrmann published an excellent smaller map, 38.7 cm (15.2 inches) in diameter. Lohrmann's style of feature portrayal, illustrated in Figure 21, was influenced by his training as a cartographer. He used hachures to show the raised crater rims and a stipple of variable intensity to indicate relative brightness of the flatter areas.

Fig. 21 Lohrmann-1878

1834 - BEER and MÄDLER

Wilhelm Beer (German banker and amateur astronomer, 1797-1850)
Johann Heinrich Mädler (German astronomer, 1794-1874)

Beer built a private observatory in Berlin and with the aid of his friend Mädler proceeded to study the moon. When it became evident that Lohrmann would not continue with the publication of his map, they decided to construct one of their own to the same scale but to be divided into four quadrants. Thus their map, 94.4 cm (37.2 inches) in diameter was published in 1834. Another edition, reduced to 32 cm(12.6 inches) in diameter, appeared in 1837. Beer and Mädler's map was based on considerably more measured positions than used by Lohrmann and contained practically all lunar features that could be observed with their 4-inch refractor. Their style of drawing was very similar to that used by Lohrmann except the hachures are less pronounced, which in many respects gives a more faithful rendition of the lunar surface. Also because of their meticulous work, they were able to add 145 names to the list compiled by Riccioli and Schröter using principally the names of prominent scientists who followed Riccioli. Beer and Mädler's drawing of Copernicus is shown in Figure 22.

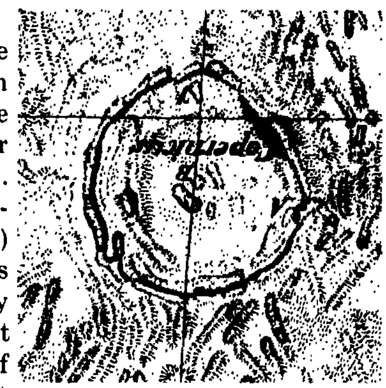

Fig. 22 Beer and Mädler-1834

1859/1876 - WEBB, BIRT, NASMYTH, CARPENTER, NEISON

After Beer and Mädler's map of 1834, some forty years passed before the next significant advance in lunar mapping by the great selenographer, Julius Schmidt. However, during the intervening time, considerable scientific interest in the moon developed in England. Thomas William Webb, an English clergyman and amateur astronomer (1806-1885) became interested in the moon around 1834 and from his own observations and Beer and Mädler's map he redrew in 1859 a much smaller lunar map in a style much like that of Schröter. Another English astronomer, William Radcliff Birt (1804-1881) conceived the idea for a large lunar map, 500 cm (200 inches) in diameter. He accomplished most of his work between 1864 and 1869 but only four sheets were completed. James Nasmyth, a Scottish engineer (1808-1890) and James Carpenter, an English astronomer (1840-1899) combined efforts and in 1874 published a book, "The Moon," which contained a series of photographs of plaster models based on drawings obtained at the telescope. Also, the English selenographer Edmund Neison

(1851-1940) published in 1876 a description of the lunar surface in "The Moon and the Condition and Configurations of Its Surface" with an accompanying 60-cm (24-inch) diameter map. Much of Neison's book was based on the work of Mädler but his map included detail from his own six-inch equatorial telescopic observations.

1878 - SCHMIDT

Johann Friedrich Julius Schmidt (German selenographer, 1825-1884)

After many years of observing the moon, Schmidt in 1866 decided to combine his many lunar drawings into a new map of the moon measuring 195 cm (76.8 inches) in diameter. He chose not to make any new positional measurements but to rely mainly on the control developed by his predecessors. In fact, he enlarged Lohrmann's map of 25 sections to twice its original scale forming the basis for his map, each section measuring 16" x 16". From observations made with his 6-inch refractor he was able to add considerably more detail as noted in his drawing of Copernicus, Figure 23. Schmidt completed his work in 1874 but his map was not published until four years later by the Prussian government.

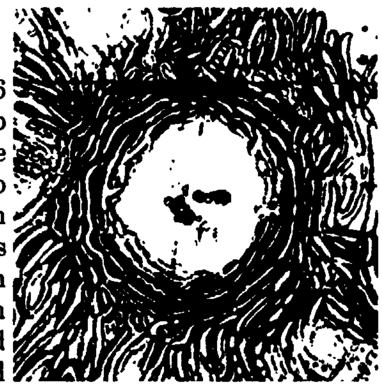

Fig. 23 Schmidt-1878

1887 - GAUDIBERT

Casimir Marie Gaudibert (French clergyman and amateur astronomer, 1823-1901)

During the latter part of the 19th century, Gaudibert carried out a number of lunar observations with an 8.5-inch reflector. In 1887 he published a 63.5-cm (25-inch) diameter lunar map. Gaudibert's lunar drawings are noted for their accuracy and inclusion of minute detail not shown on previous maps. Also in 1890 he produced a 4-inch and a 6-inch lunar globe.

1895 - ELGER

Thomas Gwyn Elger (English engineer and selenographer, 1838-1897)

Elger's map, measuring 46 cm (18 inches) in diameter and oriented with south at the top, was based on observations with an 8.5-inch refractor. His map, published in 1895, was the first English lunar map not referenced to the work of Mädler. The Copernicus area of Elger's map is shown in Figure 24.

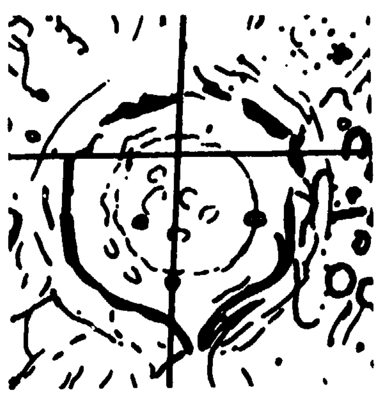

Fig. 24 Elger-1895

1898/1912 - KRIEGER

Johann Nepomuk Krieger (German selenographer, 1865-1902)

Krieger's work consisted mainly of visual observations annotated on photographs of the moon enlarged to a scale of 1:1,000,000 (11.4-foot diameter). A preliminary sample of Krieger's work was published in 1898 but he died shortly thereafter, before he could carry out his plan for complete lunar coverage. Eighteen of his sheets were later published in 1912 by Rudolf König.

1910 - GOODACRE

Walter Goodacre (English amateur selenographer, 1856-1938)

In 1910 Goodacre completed and published his large map of the moon. His original map was drawn on a single sheet with a diameter of 195.5 cm (77 inches) and afterwards it was published in 25 sections at a smaller scale of 152 cm (60 inches) to the moon's diameter.

Goodacre observed with a 10-inch Cooke refractor but his map was based primarily on photographs by Messrs. Loewy and Puiseux at Paris and the 100-inch Hooker telescope at Mt. Wilson. For control he used most of the 1,433 points measured by Saunder and because of this the positional accuracy of his map was far superior to earlier maps.

Goodacre was the first to use the rectangular grid which was subsequently adopted by Wilkins and others. His map was also reissued in 1931 at a smaller scale, measuring 76 cm (30 inches) in diameter. From Goodacre's map, shown in Figure 25 is his drawing of Copernicus, oriented with north at the top.

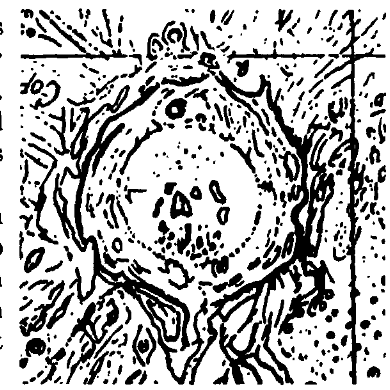

Fig. 25 Goodacre-1910

Fig. 26 Wilkins-1951

1924 - WILKINS

Hugh Percival Wilkins (English amateur selenographer, 1896-1960)

Wilkins was not a professional astronomer but he had an intense interest in the moon and spent many hours at the telescope. From visual observations commencing in 1909 and details copied from large scale photographs Wilkins published in 1924 his first lunar map measuring 152.4 cm (60 inches) in diameter. This was followed by one of 508-cm (200-inch) diameter in 1930 and a map of 762-cm (300-inch) diameter in 1946. The 300-inch map was never published at that scale, only at 100 inches, first in 1946 with a 3rd edition in 1951. The Copernicus area, Figure 26, was copied from his latest map.

1926 - ANDĚL

Karel Anděl (Czechoslovakian astronomer, 1884-1947)

Anděl's map of the moon, 61 cm (24 inches) in diameter was published in 1926. The Copernicus area of Anděl's map, shown in Figure 27, demonstrates his technique of drawing shadows to create the impression of relief. The over-all appearance of his map is quite striking compared to that of his predecessors.

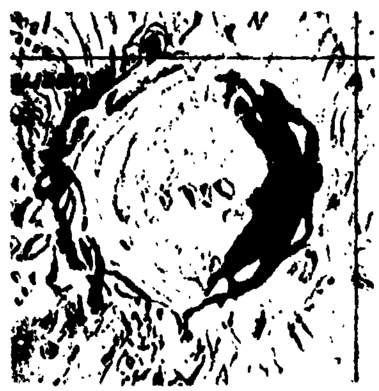

Fig. 27 Anděl-1926

Fig. 28 Lamèch-1957

1927 - LAMÈCH

Felix Chemla Lamèch (French astronomer, 1894-1962)

Lamèch, born in Ariana, Tunisia, went to Greece for his astronomical work, especially of the moon. He was director of the observatory at Corfu in 1926 and Nice in 1928. In 1927 he published his first lunar map measuring 45.7 cm (18 inches) in diameter. This was followed by two 61.5-cm (24-inch) diameter lunar maps in 1934 and 1957, the latter being published in color. Lamèch's drawing of Copernicus, shown in Figure 28, was copied from his 1957 map.

1932 - FAUTH

Philipp Johann Heinrich Fauth (German selenographer, 1867-1941)

Fauth, the last of the great visual observers, began studying the moon at the early age of eighteen. Five years later he established his first observatory and in 1894 published a topographic atlas of 25 lunar regions. Afterward Fauth made plans for a new 1:1,000,000 scale (11.4-foot diameter) lunar map to be prepared from photographs and supplemented with finer detail from visual observations. In 1895 he built his second observatory and by 1902 had discovered some 5,600 new lunar craterlets and clefts. His third observatory was built in 1911 and equipped with a 15.5-inch refractor. In 1932 Fauth issued his second lunar atlas containing 16 large-scale maps. An example of his work from this atlas is shown in Figure 29, originally drawn at a scale of 1:200,000. Fauth's lunar drawings were works of art. He used a system of shaded lines, solid and dashed, which very effectively portrays the lunar relief. Several sheets of his great 11.4-foot map of 22 sections were also issued in 1932 but only five had been completed at the time of his death in 1941. His son, Hermann Fauth, completed the remaining 17 sheets from pencil drafts and published the complete map in 1964. In 1936, Fauth also published a smaller moon map of lesser importance. This map, 87 cm (34 inches) in diameter, was drawn in six sheets to serve as a nomenclature guide for his book "Unser Mond."

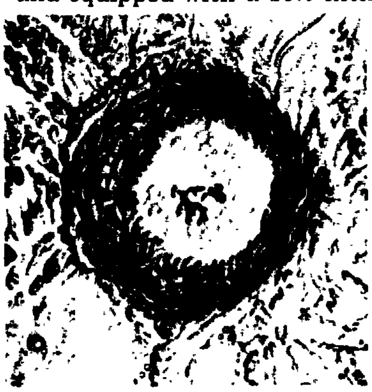

Fig. 29 Fauth-1932

IAU - 1935 - BLAGG and WESLEY

Mary Adela Blagg (English selenographer, 1858-1944)
William Henry Wesley (English scientific artist, 1841-1922)

The IAU lunar map, published in London in 1935 under the auspices of Commission 16 of the International Astronomical Union, was drawn by Blagg and Wesley. This map, based on the measures of Franz and Saunder, is in fourteen sections. The four inner sections were drawn by Wesley in 1911-1912, while the ten outer sections covering the limb regions, at a different scale, were completed by Miss Blagg in 1922. The primary purpose of the IAU map was to serve as a base upon which Mary Blagg, assisted by Dr. Karl Müller (1866-1942), could record the named and lettered formations approved by the IAU in 1932. Shown in Figure 30 is the Copernicus area copied from the section drawn by Wesley. Neither Blagg nor Wesley was a recognized visual observer and their map was drawn by reference to available photographs.

Fig. 30 IAU-1935

1959 - DOD/NASA

The successful launching of Sputnik I, on October 4, 1957, suddenly created a sense of urgency for more detailed lunar studies. In the United States, a comprehensive lunar mapping program was undertaken by Department of Defense agencies for use by the National Aeronautics and Space Administration.

For the first time professional cartographers, experienced in producing terrestrial maps from aerial photographs, began to compile similar maps of the moon. Up to this time, all maps of the moon had been drawn on an orthographic projection, which portrayed the moon as a sphere viewed from an infinite distance. Because spherical maps have their limitations, new techniques had to be developed to compile conventional moon maps on standard projections with a constant scale which could be used for planning lunar explorations.

The U.S. Army Map Service (AMS) commenced work in 1959 on a two-sheet 1:5,000,000 scale topographic lunar map which was published in 1963. This map, compiled on a modified stereographic projection, contains 1000-meter contours and 500-meter supplementary contours derived stereographically from librated earth-based photographs. Visual observations were not used in compiling the Army map.

Also in 1959 the U.S. Air Force Aeronautical Chart and Information Center (ACIC) initiated work on a 1:1,000,000 scale (11.4-foot diameter) coordinated series of lunar astronautical charts known as the LAC series. This program was carried out in collaboration with a number of scientists, mainly at the University of Manchester, England; the Pic du Midi Observatory, France; the Lunar and Planetary Laboratory, University of Arizona; and the Lowell Observatory, Flagstaff, Arizona. A total of 44 charts. oriented with north at the top, 22"x 29", covering the central front side were completed in 1967.

Shown in Figure 31 is the ACIC drawing of Copernicus taken from LAC 58, which was published in 1959. This chart was compiled entirely from photographs, without benefit of visual observations. ACIC commenced a visual observational program in 1961 at Lowell Observatory using their 24-inch refractor; shown in Figure 32 is the Copernicus portrayal from the 2d edition of LAC 58. This edition, published in 1964, used visual observations to supplement photographs. For comparison, shown in Figure 33 is an excellent photograph of Copernicus taken in 1966 on the 61-inch NASA telescope, Catalina Observatory, University of Arizona.

NASA's five successful Lunar Orbiter flights in 1966-67 returned over 1654 high-quality lunar photographs from lunar orbit. The availability of these photographs virtually negated the need for further visual telescopic observations and brought to a close an era of lunar mapping which was dependent upon the telescope for 357 years.

Fig. 31 ACIC-1959

Fig. 32 ACIC-1964

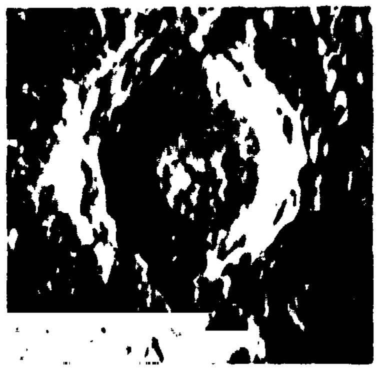

Fig. 33 Univ. of Ariz.-1966

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LUNAR NOMENCLATURE
1.3

In the section, "History of Lunar Mapping," Langrenus is credited as the first to assign names to lunar features. Since then (1645), other selenographers, such as Hevelius, Riccioli, Schröter, Mädler, Neison and Schmidt, all contributed additional names but did not always accept the names given by their predecessors.

By the year 1900, lunar nomenclature differed so greatly on various maps that the English selenographer, S. A. Saunder (1852-1912) in 1905 urged the formation of an international committee to restore some semblance of order. From the chain of events that followed, Mary Blagg emerged as one who was to have a profound influence on standardizing lunar nomenclature.

Mary A. Blagg (1858-1944) was the longtime assistant, at Oxford University Observatory, of Herbert Hall Turner (1861-1930), who was active in the reform of lunar nomenclature from 1905 on, and president of IAU Commission 17 (Lunar Nomenclature) from 1922 to 1928. Miss Blagg's work was summarized by F.W. Dyson in his introduction to "Named Lunar Formations" by Blagg and Müller, published in London in 1935:

"The desirability of uniformity in the nomenclature of lunar formations was brought before the Royal Astronomical Society by Mr. S. A. Saunder so long ago as 1905. Thereupon Prof. Turner brought up the matter before the Royal Society, and, as representing that body, before the International Association of Academies which met at Vienna in 1907. A Committee was appointed consisting of MM. Loewy (Chairman), Franz, Newcomb, Saunder, Weiss and Turner (Secretary). The name of Prof. W. H. Pickering was added - and after the death of M. Loewy, MM. Baillaud and Puiseux were added to the Committee. Before his death, Saunder had happily secured the cooperation of Miss M. A. Blagg in collating the names given to different formations in the maps of Beer and Mädler, Schmidt, and Neison. This was admirably carried out by Miss Blagg and a collated list was published in 1913 with aid of a grant from the Academie des Sciences.

"When the International Astronomical Union was constituted the question of Lunar Nomenclature was referred to Commission 17 consisting of Prof. Turner (President), Miss Blagg, MM. G. Bigourdan, W. H. Pickering and P. Puiseux. The Commission recommended that:

(1) The names in the collated list to be taken when the three authorities agree or from any one of them when the others give no name.

(2) When different names are given, each case to be decided on its merits.

(3) Names recently given and suggested names to be sparingly adopted.

"At the Leiden meeting in 1928, lists of 412 names where Mädler, Schmidt and Neison agree, and of 95 names generally accepted, though not used by all three, were submitted by Miss Blagg and approved by the Commission. Lists of 26 doubtful or inconspicuous objects and of 31 formations where names clash, were left over for consideration. Also lists of names proposed by Krieger, Müller, Wilkins and Lamèch, were prepared by Dr. Müller - a most useful supplement to the 'Collated List.' At this meeting, Prof. E. W. Brown was elected as President of the Commission and a subcommittee consisting of Miss Blagg and Dr. Müller was appointed to prepare a definitive list of names for submission at the next meeting.

"At Dr. Müller's suggestion many small formations measured by Franz and Saunder were added to the 'Collated List.' These serve the purpose of accurately defining the boundaries of larger formations. A number of indefinite objects were omitted. As regards the names given by later selenographers those suggested by Fauth, Krieger, Müller have been generally adopted, those by Lamèch more sparingly, but his suggestions are given in the notes. Wilkins' names in his earlier map (1924) were accepted but not the new ones in his 200-in. map.

"The proposals of the sub-committee were adopted by Commission 17 at Cambridge, Mass. in 1932. At the General Assembly provision was made for the publication of this definitive list of adopted names.

"These names should be strictly adhered to by selenographers. Those who may wish to add new names should ascertain from the list whether the proposed names have been already given to other formations. Also no new name should be given to a formation already named in the list. Otherwise new confusions will arise similar to those which have with difficulty been cleared away."

The Blagg and Müller 1935 List of Lunar Nomenclature, excellent as it was, did not completely survive the passage of time. In 1959 Messrs. Whitaker and Arthur of Yerkes Observatory examined the 1935 list and discovered a number of spelling errors and inconsistencies. These were noted in Table 3 of the USAF Lunar Atlas, edited by G. P. Kuiper and published in February 1960 (often referred to as the Kuiper Photographic Lunar Atlas, University of Chicago Press, 1960, civil edition). The list of nomenclature changes in the Kuiper Atlas was formally approved, with the exception of eight minor spelling changes, by the XI IAU General Assembly held in 1961 at Berkeley, California.

Also in 1961, the IAU adopted eighteen new far side names taken from the "Atlas of the Far Side of the Moon" edited by N. P. Barabashov, A. A. Mikhailov, and Yu. N. Lipskiy. In addition, Commission-16 at Berkeley reviewed the entire problem of lunar nomenclature and agreed on the following resolution:

"For designating the lunar surface features, it is recommended to follow the previous rules, revised and improved as follows:

(i) Craters and rings or walled plains are designated by the name of an astronomer or prominent scientist deceased, written in the Latin alphabet, and spelled according to the recommendation by the country of origin of the scientist named.

(ii) Mountain-like chains are designated in Latin by denominations allied with our terrestrial geography. Names are associated with the substantive Mons according to the Latin declension rules and spelling. (Three exceptions, Montes d'Alembert, Montes Harbinger and Montes Leibnitz are preserved, due to former long use).

(iii) Large dark areas are designated in Latin denominations calling up psychic states of minds. These names are associated, according to the Latin declension rules and spellings, to one of the appropriate substantives Oceanus, Mare, Lacus, Palus or Sinus. (The exceptions Mare Humboldtianum and Mare Smythii are preserved, due to former long use).

(iv) Isolated peaks are designated according to the same rules as for the craters, as well as promontories, the latter being preceded by the Latin substantive Promontorium. (Example: Promontorium Laplace).

(v) Rifts and valleys take the name of the nearest designated crater, preceded by the Latin substantives Rima and Vallis. (The exception Vallis Schröter is preserved).

(vi) Undenominated features can be designated by their coordinates. They can equally be designated according to the former classical system, by taking the name of the nearest crater, followed by a block letter of the Latin alphabet for craters, depressions and valleys, by a minor letter of the Greek alphabet for hills, elevations and peaks, and by a Roman number followed by the letter r (Ir, IIr, IIIr, etc.) for the clefts." (NOTE: The letter r following the Roman number is not used on NASA lunar charts.)

In 1963 the need arose for additional names, mainly in the limb regions, because of the publication of the University of Arizona "Rectified Lunar Atlas" (Supplement Number Two to the USAF Lunar Atlas) by Messrs. Whitaker, Kuiper, Hartmann and Spradley. At this time sixty-five new names were added to the lunar nomenclature list and subsequently approved at the XII IAU General Assembly held in 1964 at Hamburg, Germany. The Transactions of the IAU, Vol. XII B (1964) also records the following:

"An Extended Form of Blagg and Müller's Schema of Lunar Nomenclature" by D. W. G. Arthur:

"The lunar nomenclature proposed by the Lunar and Planetary Laboratory of the University of Arizona is a revised and extended form of that of Blagg and Müller, which was authorized by the Union in 1932. We have attempted to eliminate certain illogical and inconvenient situations in the Blagg and Müller scheme, but all major changes are restricted to the extreme limb regions where the Blagg and Müller scheme, and for that matter, all previous maps, are somewhat unrealistic. The scheme is based on a lengthy and thorough survey of the best available photographs and is embodied in the following documents.

(i) **The System of Lunar Craters,** Communications of the Lunar and Planetary Laboratory. This work is in four parts with a catalog and map for each of the four lunar quadrants.

(ii) **Lunar and Planetary Designations,** Arthur and Agnieray, University of Arizona Press. A two-color map in four parts.

(iii) **The Rectified Lunar Atlas,** Whitaker et al., University of Arizona Press. This gives the names but not the letters.

(iv) The L.A.C. lunar topographic maps at 1:1,000,000 of the Aeronautical Chart and Information Center of the U. S. Air Force. These are available by subscription.

The above indicates that the proposed scheme is not subject to the drawback of limited distribution, which somewhat hampered the diffusion and acceptance of the Blagg and Müller nomenclature.

"As already stated, no major changes were made in the central areas of the disk, except the deletion of a few names which were duplicated elsewhere. In these areas we merely intensified the existing scheme by adding additional letters. The situation near the limb is basically different in that recent intensive cartographic work, coupled with a changeover to conformal projection, makes the Blagg and Müller scheme quite inadequate for contemporary lunar cartography. To eliminate some serious and widespread difficulties, some 60 new names were added in the extreme limb regions. Almost all of these fall in areas which are very poorly represented in all the older maps.

"The demands of tradition and continuity were given full weight throughout, even though these often prevented the development of a completely logical scheme of lunar nomenclature."

NASA's five successful Lunar Orbiter Missions, flown during the 13-month period from August 1966 to September 1967, acquired new far side coverage of a much higher resolution than the partial coverage taken by Lunik 3 in 1959. For the first time, photographs were available to completely map the far side features but not in time for the XIII IAU General Assembly held in 1967 at Prague, Czechoslovakia. Accordingly, the IAU Commission 17 in 1967 adopted the following resolution:
(NOTE: All lunar work of Commission 16 was combined with Commission 17 in 1964).

"The assignment of names and permanent designations to features on the far side of the moon will be postponed until the Fourteenth General Assembly. As an interim measure, a Working Group will assign numbers to about 500 major lunar formations. It has been agreed that the members of this Committee–none of whom is personally and directly engaged in the work of Lunar Topography–should represent the work of each country through the National Astronomical Committees concerned. It is desirable that, in a general way, the work on Lunar Nomenclature be guided in conformity with the decisions already adopted by the IAU defined by Resolution No. 2 of Commission 16, taken during the General Assembly at Berkeley in 1961 (Trans. IAU XI (1961)–235) and completed by the list of names adopted in 1964 (Trans. IAU XII (1964)–202)."

In 1970 at the XIV IAU General Assembly held at Brighton, England, 513 new names of far side features were approved. A complete report on lunar nomenclature by the working group of Commission 17 of the IAU (1970) was published in "Space Science Reviews" (12 (1971) 136-186) by D. Reidel Publishing Company, Dordrecht-Holland. In recognition of the first manned landing on the moon, the IAU in Brighton agreed to allow an exception to the tradition of using only names of deceased scientists. Names were allowed for the three living astronauts of Apollo 8, who were the first to orbit the moon and to see and photograph its far side, and the three living astronauts of Apollo 11, who participated in the first landing on the moon.

The three astronauts of Apollo 8 were assigned craters in the vicinity of the crater Apollo on the far side, and those of Apollo 11 were assigned to three previously unnamed small craters near the landing point on Mare Tranquillitatis. In addition, it was agreed that six distinguished living cosmonauts of the U.S.S.R. be accorded similar recognition by naming craters in the vicinity of Mare Moscoviense on the far side.

Persons mainly responsible for additions to the Blagg and Müller 1935 list of nomenclature are: from 1959 through 1967, Arthur and Whitaker, University of Arizona; from 1967 through 1970, Menzel, Harvard College Observatory, assisted by Minnaert (The Netherlands), Levin (USSR), and Dollfus (France). NOTE: In 1967, Commission 17 appointed a lunar nomenclature committee consisting of Menzel (Chairman), Mikhailov, Minnaert, and Dollfus. (In 1968 Mikhailov was replaced by Levin.) This committee, charged with the responsibility of selecting new names for the far side features, solicited recommendations from numerous sources, i.e., members of Commission 17 and many scientists from various countries. From an extensive list, the committee made a final selection of 513 new far side names.

A consolidated alphabetical listing and feature location of all primary lunar names which have been approved by the IAU was published by ACIC in 1971 (Index of Lunar Formations) under the sponsorship of NASA. Copies are available from Headquarters NASA (SM) Washington, D. C., 20546 or DMA Aerospace Center (PPCC) St. Louis AFS, Missouri 63118.

At the IAU general assembly held in August, 1973 in Sydney, Australia, a revised system of lunar nomenclature was adopted. This revised system divides the lunar surface into 144 named regions at 1:1,000,000 scale by means of parallels of latitude and meridian arcs. Each of these 144 regions is subdivided into sixteen provinces at 1:250,000 scale in the following manner. Each region is first subdivided into quadrants lettered A, B, C, and D, quadrant A being the upper left quarter, and quadrants B, C, and D being consecutively assigned in a clockwise direction. Each of these lettered quarters is further subdivided into four equal sections and each section is assigned a number, with 1 being the upper left, and 2, 3, and 4 assigned consecutively in a clockwise direction. Thus each province, in addition to carrying a province name (none of which duplicate region names) can be identified and located by a code designation consisting of its region number, letter (A, B, C, D), and number (1, 2, 3, or 4). Each region and each province is named for some prominent feature (preferably a crater) located within it.

It was resolved that Greek letter designations for lunar elevations would be dropped. Also to be dropped are crater names designated by use of a Roman capital letter; large or otherwise important craters previously designated by this system will be renamed with new and distinctive names. Ridges, previously unnamed will be called dorsa (singular, dorsum). Rima and rimae systems will receive new and appropriate designations. Crater chains will be designated catena. Very small features requiring identification for some special reason may be assigned male or female first names from an international list approved by the IAU. Such names must not have more than three syllables.

In addition, the IAU corrected some 19 names from the list adopted in 1970 (these changes were, for the most part, minor spelling corrections), and added one name to the list. Astronaut-named features in the vicinity of the Apollo landing sites and a list of names to be used as province names were approved, as well as a list of 69 names for assignment to lunar maps in production.

Previously assigned lunar names have, with few exceptions, been those of distinguished deceased scientists. At the 1973 meeting, it was decided that future assignments might also contain the names of "distinguished, deceased contributors to human culture and knowledge, such as writers, painters, musicians, etc., chosen on an international basis." Political, military and religious figures, as well as modern philosphers, were excluded. Subsequent to the 1973 meeting, however, there was some discussion as to the desirability of using non-scientists' names, and until this question is fully resolved, an unofficial moratorium has been imposed on the use of non-scientists' names for lunar features.

2.0 LUNAR PHOTOGRAPHY

Photographs of the moon are the principal basic source material for lunar mapping as is the case in most other fields of lunar scientific investigation. Earthbased telescopic photography providing coverage of the lunar nearside was the only available photography until the advent of U. S. and Russian camera carrying spacecraft in near lunar proximity. While photography accomplished from lunar orbit has largely replaced earthbased materials for definition of lunar topography, maps and control derived from earthbased photography continue to be of current import.

Photography accomplished by the unmanned Lunar Orbiter Spacecraft and taken from lunar orbit during Project Apollo Missions provide the principal photographic information for current lunar cartographic endeavors. The photography of Apollo Missions 15-17 is optimum for control development and map compilation processes.

Earthbased Photography 2.1

Ranger Photography 2.2

Lunar Orbiter Mission Photography 2.3

Apollo Mission Photography 2.4

Surveyor Photography 2.5

2.1 EARTHBASED LUNAR PHOTOGRAPHY

Lunar Photography was accomplished soon after the development of the photographic process in 1839. One of the originators of this process, L. J. M. Daguerre, was encouraged to attempt a photograph of the moon by D. T. J. Arago, then Director of the Paris Observatory. This first effort failed to produce any recognizable features due to underexposure. However, it served as a basis for further experiments by J. W. Draper, who produced a successful photograph of the moon in 1840, using a 12 inch mirror and a 20 minute exposure.

After Draper's success, numerous astronomers experimented with lunar photography. During the rest of the 19th century, there was a continual increase in the quality of lunar photographs as a result of progress in telescope construction and improvements in photographic materials. By 1850, exposure times had been reduced to less than a minute, resulting in photographs capable of depicting the major features on the moon's surface. The shorter exposure time reduced the problems of telescope guidance and image motion caused by the earth's atmosphere.

This combined progress in telescopes and photographic materials made possible high quality lunar photographs with sharp images that could stand considerable enlargement. As a result, two extensive lunar photographic programs were begun at the Lick and Paris Observatories in the last decade of the 19th Century.

Edward S. Holden, the first director of the Lick Observatory, used the 36 inch refractor of 17.34 meters focal distance for lunar photography. On the original negatives, the diameter of the moon's image varied from 4.9 inches at apogee to 5.5 inches at perigee. A part of this photography was published as the "Lick Observatory Atlas of the Moon" in 1896-97. The original negatives were enlarged to represent a diameter of the lunar image of about 38 inches in the published atlas.

At the Paris Observatory, M. Loewy and P. Puiseux embarked upon an extensive program of lunar photography using the "grand equatoreal coude," a refractor of 60 centimeters (24 inches) aperture and a focal length of 18.22 meters. In the focal plane of this instrument, the diameter of the lunar image varies between 6.1 inches and 6.8 inches from apogee to perigee. Eighty enlargements of this series were published as the "Atlas Photographique de la Lune," 1896-1909. These enlargements were selected from approximately 2000 lunar photographs taken during this period and were the standard work on the subject for several decades.

Until the advent of lunar photography, illustrations of the moon's surface consisted of drawings from visual observations made by different investigators. There are both advantages and disadvantages in using the photographic technique as opposed to visual observations. One major advantage of photography is that it presents an impartial and permanent record of the moon's surface from one epoch to another. The accuracy of visual observations depends upon the interpretation and drawing skill of the observer. It sometimes happens that an excellent observer is a poor draftsman and vice versa.

Disadvantages of the photographic method involve telescopes, film emulsions, and the earth's atmosphere. It is necessary that a photographic telescope be equipped with a precise driving mechanism to compensate for the earth's diurnal motion. The telescope is driven in right ascension at a rate equal to and opposite from the earth's rotation, so that the image remains in the same position on the negative. Otherwise, the photograph will be blurred or streaked due to motion of the imagery during exposure.

Film emulsion speed is directly related to telescope tracking and the blurring effects of the earth's atmosphere. Emulsion speed determines the exposure time that is necessary to properly record imagery. As emulsion speeds were increased, exposure time was reduced and sharper images were obtained. Also, smaller and more delicate lunar features could be photographed as a result of reducing these blurring effects. An example of this improvement can be observed by comparing lunar photographs using modern emulsions with earlier efforts taken with the same telescope. The first photographs of the moon required several minutes of exposure, while modern lunar photography can be taken in less than a second.

A major distortion in lunar photography is due to image motion caused by atmospheric turbulence called "seeing." This motion is readily observed in the telescope's focal plane and it occurs in local patterns over the moon's disc. During a long exposure of the moon, image motion blurs the recording of large prominent features and obscures the finer detail. An exposure time on the order of one second or less "freezes" a feature's moving image in some part of its random cycle. Finer details will then be registered on the photographic plate, though not necessarily in their true position.

Visual observations have an advantage in regard to image motion. On nights of good seeing, there are brief moments of unusual steadiness in the atmosphere. Fine details can be visually observed which cannot be recorded on the photographic plate. It is not possible to anticipate these moments of steadiness so that they could be made to exactly coincide with the exposure time. Therefore, some blurring always occurs in photography. For this reason, drawings of lunar and planetary surfaces resulting from visual observations are usually more detailed than photographs.

As a photographic subject, the moon offers various problems in light intensity. There is a difference in the luminosity of lunar features, particularly between bright areas such as Aristarchus and Censorinus and the dark Maria. However, the major problem involves the difference in the intensity of reflected sunlight from different parts of the lunar disc.

Features near the terminator are illuminated by low grazing sunlight and the amount of reflected light is considerably less than from areas under high solar illumination. It is estimated that this difference in the intensity of reflected sunlight is a factor of 1000. There are no film emulsions presently available that can record such a range in luminosity.

Naturally, when the exposure time is set to record the terminator regions, the areas under high illumination are over-exposed. If a shorter exposure time is used to depict the bright areas, the terminator region is under-exposed and the moon exhibits a false age. In modern lunar photographic efforts, such as the recent extensive program at the Pic du Midi Observatory, it is customary to vary the exposure time to adequately record all segments of the moon's sunlit disc.

Lunar photographic atlases of the 20th century depict the moon's surface by regions under different solar illuminations. Usually, small lunar features are only visible near the terminator, while bright streaks and rays are prominent under high solar illumination. Therefore, a complete photographic description of the moon's surface requires views containing different illumination angles. An example of this type of atlas is the Photographic Lunar Atlas (USAF Lunar Atlas), edited by G. P. Kuiper. The illustrations are based on enlargements of the best photographs of the moon taken at the Lick, McDonald, Mt Wilson, Pic du Midi, and Yerkes Observatories. It presents 44 different regions of the moon as viewed under four to five different solar illuminations.

The quality of photography in the 20th century had improved by advances in film emulsions and telescopes. Refracting telescopes reached their size limit with the 40 inch lens at the Yerkes Observatory. Lenses of this size absorb a considerable amount of light due to their thickness.

Also, refractor lenses are only supported by their thin edges and apertures larger than the 40-inch would have a tendency to sag and warp under their own weight. Therefore, the desire for greater light grasp and resolution, through larger apertures, had to be satisfied with reflecting telescopes.

The reflecting telescope was invented by Sir Isaac Newton to eliminate the defect in refractors known as chromatic aberration. Different colors of visible light were brought to a slightly different focus when refracted by a single lens. If a refracting telescope were focused for blue light, the other colors would be out of focus creating fuzzy images. Newton hastily concluded that this situation could not be corrected. This proved to be an incorrect conclusion as J. Dollond developed the achromatic refractor almost a century later.

During the 20th century, improvements have been made in reflecting telescopes and some very large mirrors were cast. These included the 200-inch at Palomar Observatory and the 120-inch at Lick Observatory. Such instruments offer a tremendous increase in light gathering and resolution capabilities. Although these telescopes are primarily used as astronomical cameras for deep space photography, some excellent lunar photographs have been obtained. Several lunar photographs taken with the Lick 120-inch reflector probably represent the highest resolved earthbased lunar photography.

Theoretically, the resolution of a telescope increases directly with the aperture of the objective lens or mirror. In practice, this situation is considerably modified by seeing and atmospheric conditions. The volume of the column of atmosphere, through which moonlight must pass to reach the telescope, increases with the aperture and there is more likelihood of turbulance and other seeing defects. On nights of indifferent seeing, it is often possible to obtain a sharper lunar image by reducing the aperture. Therefore, smaller telescopes located in areas of good "seeing" can produce better results than larger instruments under average conditions.

For the above reasons, the selection of an observatory to carry out an extensive program of lunar photography for pre-Apollo mapping was greatly influenced by "seeing" conditions. Pic du Midi Observatory in the Pyreress Mountains of Southern France was selected as it is known to have moments of excellent "seeing" and transparent skies. The telescope in use was the "grand equatoreal coude" refractor, formerly used at the old Paris Observatory. Later in the program, a 40 inch r flector was also used for lunar photography.

Unlike its predecessors, the lunar program at Pic du Midi was not primarily engaged in feature portrayal of the earthside hemisphere. A major goal of this effort was to develop a large photographic library for the determination of relative heights through shadow measurements. It was designed to accumulate a large variety of slightly different solar illuminations for a more descriptive analysis of relative heights. For example, the profile of a large crater's floor can be obtained by measuring the shadows cast by the east and west walls under different conditions of morning and evening illuminations. This results in the determination of the height of the walls above different parts of the crater's floor and the differences describe the undulations. In the past, shadow measurements had been accomplished visually using a filar micrometer.

Another aspect of this program was to develop a series of photographic observations for the determination of selenocentric positions on the moon. An extensive photographic effort was required since each observation must contain the proper quality, phase, and libration angles.

The photographic program at Pic du Midi Observatory extended through most of the 1960's and over 50,000 individual photographs were accumulated. Whenever the moon's position and atmospheric conditions were suitable for photography, a series of about 60 to 100 negatives were exposed. Exposure times varied from 0.1 to 1.6 seconds and occasionally different emulsions were used in the same series. A detailed description of lunar photographic work at Pic du Midi is given in Reference 2.7.3.

The minimization of the effects of image motion caused by the earth's atmosphere was another desirable characteristic achieved. A short exposure "freezes" the moving image in some part of its random motion and there may be considerable distortion introduced into the recorded position of a feature. Using a series of photographs with short elapsed time between each photograph makes it possible to treat a small sequence as a single observation. The mean position derived for each feature from measurements made on several photographs of the series provides photographic coordinates having reduced error due to image motion.

Another effort to resolve this problem was made with the 61 inch astrometric reflector at the U. S. Navy Observatory, Flagstaff, Arizona. One aspect of this telescope is that it can be automatically guided in both right ascension and declination. Long exposures of the moon, usually from 20 to 60 seconds, can be accomplished as a result of precise tracking. The purpose is to average the image motion photographically. A very small bright crater appears to be surrounded by a light haze or halo, caused by the image motion during exposure. The center of this image is a more precise geometric position than can be obtained from a single short exposure.

Additional information on earthbased lunar photography is contained in References 2.7.31 - 2.7.37.

2.2 RANGER MISSION PHOTOGRAPHY

The Ranger Mission objective "to obtain close-up pictures of the lunar surface which would be of benefit to both the scientific program and the manned program" was accomplished by Ranger Missions VII, VIII and IX in the 1964-65 period. These three vehicles impacted the moon in pre-selected areas to obtain photographs of lunar maria, highlands and highland basins.

Each Ranger vehicle carried a wide and narrow angle television camera system which differed in the field scanned and time interval between exposures. The narrow angle camera frame sequence was more than ten times faster than the wide angle and resulted in a maximum definition of lunar surface detail to a dimension of one meter. The wide angle system was composed of two cameras having 25mm and 76mm focal lengths. The narrow angle system contained two cameras of each focal length. The camera fields of view were arranged to provide overlapping coverage, so that, with a minimal terminal orientation, a nesting sequence of photographs would be obtained from at least one of the wide angle cameras. The television signals received from the Ranger transmitter system were displayed on a cathode ray tube and photographed, providing a 35mm film reconstruction of the original television photography.

Prior to impact, Ranger VII transmitted 4038 photographs during the last 17 minutes and 13 seconds of its flight; Ranger VIII transmitted 7137 photographs during the last 23 minutes and 4 seconds; Ranger IX transmitted 5814 photographs during the last 18 minutes and 49 seconds. Ranger Mission Photo coverage is portrayed on Photo Index I(1) and additional information on Ranger Mission Photography is contained in references 2.7.25 - 2.7.30.

2.3 LUNAR ORBITER MISSION PHOTOGRAPHY

Five unmanned Lunar Orbiter Missions providing nearly complete photo coverage of the lunar surface were accomplished from August 1966 - August 1967. Photographic acquisition was planned to accomplish photography of potential Apollo landing sites and scientifically interesting areas, broad lunar coverage and photo-mapping material for the moon's nearside.

The Lunar Orbiter Camera contained a dual lens system that produced imagery from 80mm (medium resolution) and 610mm (high resolution) focal length lenses on 70mm film which was vacuum flattened during exposure. The camera fiducial system was composed of sawtooth notches along two opposite sides of the camera frame. A velocity/height sensor regulated movement of the film platen to avoid image smear. Image motion compensation did not operate properly for Lunar Orbiter Mission I high resolution photography.

Film development was performed aboard the spacecraft by a non-liquid development process. Transmission of photo imagery to earth was accomplished through a segmented electronic scanning of film and conversion of film density to an electrical video signal. Received signal for each photo segment or 'framelet" was reconverted to imagery on a kinescope tube and recorded on 35mm film. A single 80mm focal length photo is composed of approximately 40 framelets and 85 framelets were required to reconstruct the larger format of a 610mm exposure.

In addition to the general lunar coverage provided by the Orbiter Missions, the equatorial orbits of Mission I, II, and III resulted in specific site photos from a nominal lunar altitude of 46 kilometers. Features as small as 1-2 meters were resolved in areas of good quality long focal length photography. Lunar site coverage was also obtained by polar orbiting Mission V from a 100 km or greater altitude with corresponding scale and resolution reduction. Mapping type photography of the lunar nearside was accomplished by polar orbiting Mission IV from a nominal altitude of 2500-3000 kilometers resolving features of 60-80 meters dimension in long focal length photos. However, areas of stereo coverage of long focal length photography are limited.

The principal deterrent to cartographic exploitation of Lunar Orbiter photography, has been photographic distortion introduced by the scanning and transmission process which segments each photograph into individual framelets. Generally, the displacements are of sufficient magnitude to cause observable discontinuities in images occurring at the edges of adjacent framelets. A pre-exposed film reseau was instituted beginning with the 2nd Orbiter Mission and has provided a basis for compensating for distortions introduced by inprocess photo segmentation. The photogrammetric utility of Lunar Orbiter Mission I photography is limited by the absence of this internal reseau.

Precise correction for photo transmission distortions in Lunar Orbiter photos can best be obtained in the analytic photogrammetric triangulation process where corrected camera system coordinates for each measured image is obtained by mathematical adjustment into the film reseau and camera reseau systems. Cartographic compilation processes requiring physical assembly of photography used are subject to residual errors in the positions derived from adjacent framelet models. Similarly, photo mosaic compilations contain mismatch of detail along framelet edges and pictorial continuity is disturbed by the edge lines.

Additional detail concerning characteristics and operation of the Lunar Orbiter Photographic Systems is available in references 2.7.1 - 2.7.8. Camera calibration data is furnished by references 2.7.9 - 2.7.12. The extent of Lunar Orbiter photographic coverage is shown in Photo Indices I(2) - I(5) and II(1) - II(4).

2.4 APOLLO MISSION PHOTOGRAPHY

Apollo Mission 8's orbit of the moon in December 1968 resulted in the first return to earth of original film exposed in lunar proximity. Mission 8 and follow-on Missions 10, 11, 12, and 14 (May 69-February 71) employed Hasselblad electric cameras to obtain coverage of potential landing sites and areas of scientific interest. Imagery is recorded on 70mm film. Maurer 16mm format sequence photography was also obtained but is not deemed cartographically significant.

Interchangeable film magazines and lenses were employed with the Hasselblad camera to obtain both black and white and color photography as well as near verticals and obliques from 80mm, 250mm, and 500mm focal length lenses. Use of these lens combinations resulted in photography having nominal scales ranging from 1:220,000 to 1:1,400,000. The 80mm lens was also employed in taking strips of stereoscopic coverage along mission flight paths.

Several factors tend to limit the precision of cartographic-photogrammetric results obtainable from Apollo Mission Hasselblad photography. The camera has no calibrated fiducial system to allow recovery of interior orientation and contains no device to assure flattening of film during exposure. Even determination of the geometric center of each photograph is obscured as the edge of film rollers are imaged on two sides of each photo rather than the camera frame. Also, the camera has been deployed through a spacecraft window of three panes thickness and variation in calibration is reflected with interchange of film magazines.

The Apollo 15-17 photographic materials were collected by the components of the Scientific Instrument Module (SIM) which has two major photographic instruments, a panoramic camera and a Metric Camera System. The Metric Camera System consists of a mapping camera, associated stellar camera, laser altimeter, and precise relative timing equipment. The mapping camera has a 76mm focal length and a 115mm format. Inscribed on the focal plane plate is a 10mm reseau which is recorded on every photograph by natural illumination. Also present are eight artificially illuminated fiducial marks. The camera has the capability to compensate for forward motion and to automatically set the shutter interval based upon sensor information of lunar surface brightness. At a 110 km altitude, a mapping camera exposure will cover approximately a 170 km x 170 km area. Under optimum conditions, the resolution of the camera is 90 lines per millimeter. The stellar camera has a 76mm focal length and a format size of 32mm x 25mm. This camera has a 5mm reseau with four additional fiducial marks on the exterior of the format. Premission stellar calibration provides a relationship between the mapping and stellar cameras. The laser altimeter provides the vehicle altitude at specific times during the mapping camera exposure sequence. The altitude is recorded along with the time of the observation on the mapping camera film.

The panoramic camera employs an optical bar and is configured as a single, self-contained unit with no separately housed components. The camera lens system and variable slit assembly (the optical bar) are supported in a roll frame which rotates in the scan direction (crosstrack) during camera operation. The roll frame is supported by a gimbal assembly which tilts a front prism fore and aft for stereo coverage and forward motion compensation. The lens has a focal length of 610mm (24 inches). The image format is 4.5 by 45.24 inches with the field of view being 10° 46' by 108°. Convergent 25 degree stereo coverage is obtained by tilting the roll frame on alternate exposures 12°5 forward and aft. This results in 10 percent overlap of consecutive forward or aft frames and 10 percent overlap between stereo pairs. At a 110 km altitude the panoramic camera will cover approximately a 22 km x 340 km area. Under optimum conditions, the panoramic camera resolves 135 lines per millimeter.

Individual mission camera calibration data is on file at Mapping Sciences Laboratory, NASA Manned Spacecraft Center, Houston, Texas. Extent of photo coverage is shown in Indexes I(6) - I(22) and II(5) - II(19). References 2.7.13, 2.7.17 - 2.7.24, 2.7.39 - 2.7.51 provide more detailed indexes and information.

2.5 SURVEYOR PHOTOGRAPHY

Surveyor missions demonstrated a soft lunar landing technique as a precursor to the Apollo program which utilized similar final descent and landing system technology. They provided the only lunar surface photography prior to that accomplished in the manned Apollo missions.

Four of the surveyors soft-landed at mare sites within the Apollo zone. The fifth and final surveyor was then successfully used for scientific investigation of a contrasting site in the lunar highlands.

The vast quantity of television pictures returned by the Surveyor spacecraft were obtained during a variety of operations and experiments which included: wide and narrow angle panoramas, special area surveys, varying sun angles, images using polarizing filters, color photographs reconstructed from images obtained with color filters, and photography of star fields, solar coronas, planets, eclipses, scientific experiments and equipment.

A special mirror on Surveyor VII was used to provide a small amount of stereoscopic coverage and to facilitate distance measures. The Surveyor VI spacecraft was moved several hours after landing by a controlled static firing of the vernier engines causing the spacecraft to hop. The change in position provided a stereoscopic base for accomplished photography.

There were 87,674 images transmitted from the five Surveyors: 11,240 from Surveyor I, 6,326 from Surveyor III, 19,118 from Surveyor V, 29,952 from Surveyor VI and 21,038 from Surveyor VII.

The areas covered by Surveyor television pictures range from 1.2 meters to a distance of 30 kilometers from the camera stations. Surveyor III and V landed within lunar craters.

The Surveyor television camera system contained a variable focal length, however, only two settings were used: (1) 25 mm focal length with a 25.3 degree field; (2) 100 mm focal length with a 6.43 degree field. An adjustable iris provided effective aperture changes from f/4 to f/22. The size of the image frame in the vidicon tube was 11 mm square and was scanned in either a 200 line mode or a 600 line mode. The 600 line mode was used for the greatest percentage of images recorded. Surveyor photography is of very limited value for cartographic work.

2.6 PHOTOGRAPHIC SUPPORT DATA

Photographic Support Data has been produced as a companion product to photography obtained from Lunar Orbiter and Apollo photographic missions. It tabulates reduction of data obtained from spacecraft and earthbased instrumentation bearing on the position and attitude of the taking camera. The data is in tabular form (Figure 1) and is expressed in terms required by photogrammetric users to establish lunar surface positions. Discussion of the application of Photo Support Data to lunar control derivation is contained in Dossier Section 3.

Lunar Orbiter Mission Photographic Support Data . . . 2.6.1

Apollo Mission Photographic Support Data 2.6.2

APOLLO 15 A15 R-23 MAP 12/71 FIN PAGE - 850

	YEAR	MONTH	DAY	HOUR	MINUTE	SECOND
GMT	71	7	31	15	57	52.282
GET			5	2	23	51.489

STATE VECTOR	X	Y	Z	X DOT	Y DOT	Z DOT
1950.0	659.4554138	1130.4409637	1296.2100983	1.4647485	-.7070134	-.1450562
SELENOGRAPHIC	1635.7784119	325.0278854	782.0004349	.2288269	-1.6085944	.1626650
SIGMA(SELENO)	.28	1.99	.21	.002	000	.001

LONGITUDE OF NADIR POINT	11.2382497 DEG	LATITUDE OF NADIR POINT	25.1215730 DEG
SIGMA NADIR LONGITUDE	.0012039 DEG	SIGMA NADIR LATITUDE	.0001269 DEG
LONG OF CAMERA AXIS INTERSECT	9.5243126 DEG	LATI OF CAMERA AXIS INTERSECT	24.8180840 DEG
SPACECRAFT RADIUS	1841.9931488 KM	SPACECRAFT ALTITUDE	103.9031525 KM
SIGMA SPACECRAFT RADIUS	.0000048 KM	AZIMUTH OF VELOCITY VECTOR	276.5085182 DEG
MEAN ALTITUDE RATE	-.0115763 KM/SEC	HORIZONTAL VELOCITY	1.6328400 KM/SEC
TILT AZIMUTH	259.3102150 DEG	TILT ANGLE	24.6647062 DEG
SIGMA TILT AZIMUTH	.0049669 DEG	SIGMA TILT ANGLE	.0019258 DEG
SUN ELEVATION AT PRIN GRND PNT	25.4933844 DEG	SUN AZIMUTH AT PRIN GRND PNT	102.4556646 DEG
LONGITUDE OF SUBSOLAR POINT	71.3356352 DEG	LATITUDE OF SUBSOLAR POINT	.2265720 DEG
ALPHA	22.3311062 DEG	SWING ANGLE	270.4434013 DEG
EMISSION ANGLE	26.2477863 DEG	SIGMA SWING ANGLE	.0049965 DEG
PHASE ANGLE	41.3160172 DEG	NORTH DEVIATION ANGLE	190.7063103 DEG
PHI	24.6640565 DEG	X-TILT	.1850339 DEG
SIGMA PHI	.0019224 DEG	SIGMA X-TILT	.0020333 DEG
KAPPA	168.9072723 DEG	Y-TILT	-24.6639204 DEG
SIGMA KAPPA	.0019867 DEG	SIGMA Y-TILT	.0019216 DEG
OMEGA	.1850339 DEG	HEADING	-101.1776962 DEG
SIGMA OMEGA	.0020883 DEG	SIGMA HEADING	.0021993 DEG
SCALE FACTOR	.0000000 M/KM	LASER SLANT RANGE	119.0249996 KM
SPACECRAFT ALTITUDE (LASER)	108.1658058 KM	ALTITUDE DIFFERENCE	4.2626534 KM

Figure 1

2.6.1 LUNAR ORBITER MISSION PHOTO SUPPORT DATA

Successive editions of Lunar Orbiter Mission Photo Support Data were produced by the Boeing Company under NASA Contract during the period 1967-1969. The continued refinement of the data during this time resulted in a September 1969 publication of final data for each Lunar Orbiter Mission.

Determination of spacecraft orbit from earthbased tracking data was accomplished with computer program ODPL, generally using data arcs of three orbit duration. Jet Propulsion Laboratory's Developmental Ephemeris 19 (DE-19) provided planetary ephemeral information. NASA Langley Research Center's Gravity Models LRC 11/11 was used for the low inclination orbits of Missions I, II, III and model LRC 7/28B was employed in reduction of the high inclination orbits of Missions IV and V.

Control of camera attitude in the Lunar Orbiter System was dependent upon a star tracker's establishment of spacecraft orientation. The orientation data provided by this system reflected the directed spacecraft maneuvers relative to the celestial reference, with confirmation and adjustment based on telemetered gyroscopic data. Lesser accuracy was obtained in Lunar Orbiter Mission IV camera attitude information as maneuvers were made relative to previously established attitude rather than updating orientation through celestial alignment. Time of exposure, required for correlation of both position and attitude data, was recorded to .1 second.

2.6.2 APOLLO MISSION PHOTO SUPPORT DATA

Photo Support Data pertinent to Apollo Mission Photography has been computed and published by the NASA Manned Spacecraft Center. Data is available for Hassleblad 80mm focal length stereo strip photography obtained during Missions 10, 12 and 14, and for Apollo 12, 500mm focal length coverage of the Fra Mauro and Descartes areas. It is also being published for the Metric Camera photography of Missions 15-17.

In computing Photo Support Data, the spacecraft orbit has been determined with computer program HOPE generally using tracking data for individual areas of lunar frontside photography with extrapolation to farside coverage. Lunar gravity model L1, Koziel's libration model and Jet Propulsion Laboratory's planetary ephemeris DE-19 have been employed as input. Orientation and positional information presented in Apollo Photo Support Data has been computed with the Apollo Photograph Evaluation Program (APE) and sample output is shown in Section 2.6, Figure 1.

Camera orientation has been derived through relation of camera axes to spacecraft body axes and inertial measurement unit gimbal angles. In the Hassleblad Photo Support Data, an uncertainty of ± 1° was considered to exist in relating camera to spacecraft axes. However, photo triangulation performed with mission photography and Photo Support Data reflects systematic orientation angle discrepancies of from 1° - 4°. The camera orientation information expressed for the Metric Camera (Apollo 15-17) missions is generally in good agreement with orientation information derived from reduction of stellar photography. Systematic differences of several minutes of arc and smaller random differences exist.

Unfortunately, precise time of photo exposure was not obtained for Hassleblad photography of Missions 10, 12 and 14, and data has necessarily been produced without direct correlation to individual photo frames. This Photo Support Data is expressed at one second intervals over the time period during which each photo strip was accomplished. In the case of Apollo Metric Camera Missions, Photo Support Data is referenced to the time of individual exposures.

Camera orientation data resulting from reduction of Apollo 15-17 stellar photography is considered more accurate than orientation data shown in Photo Support Data. Where stellar photographic reductions are not available and orientation data for vectoring laser altimetry is required, adjustment of Photo Support Data values is recommended based on stellar photo-Photo Support Data differences existent for other portions of the particular mission.

Selenodetic control development through analytical photogrammetric triangulation of photographs accomplished by Apollo Missions 15-17 mapping cameras, has as a by-product of this work, provided an independent evaluation of spacecraft position information contained in Photographic Support Data. Interorbit biases in spacecraft positions which generally range from 300-600 meters horizontally and 50-150 meters vertically have been defined for current editions of Photographic Support Data. In isolated instances biases of more than one kilometer have been shown to exist. Updated spacecraft positions which minimize spacecraft ephemeris inconsistencies are available for all Mission 15 orbital photographic revolutions and selected Mission 16 and 17 revolutions.

More detailed discussion of Apollo Photo Support Data is contained in references 2.7.22 - 2.7.24.

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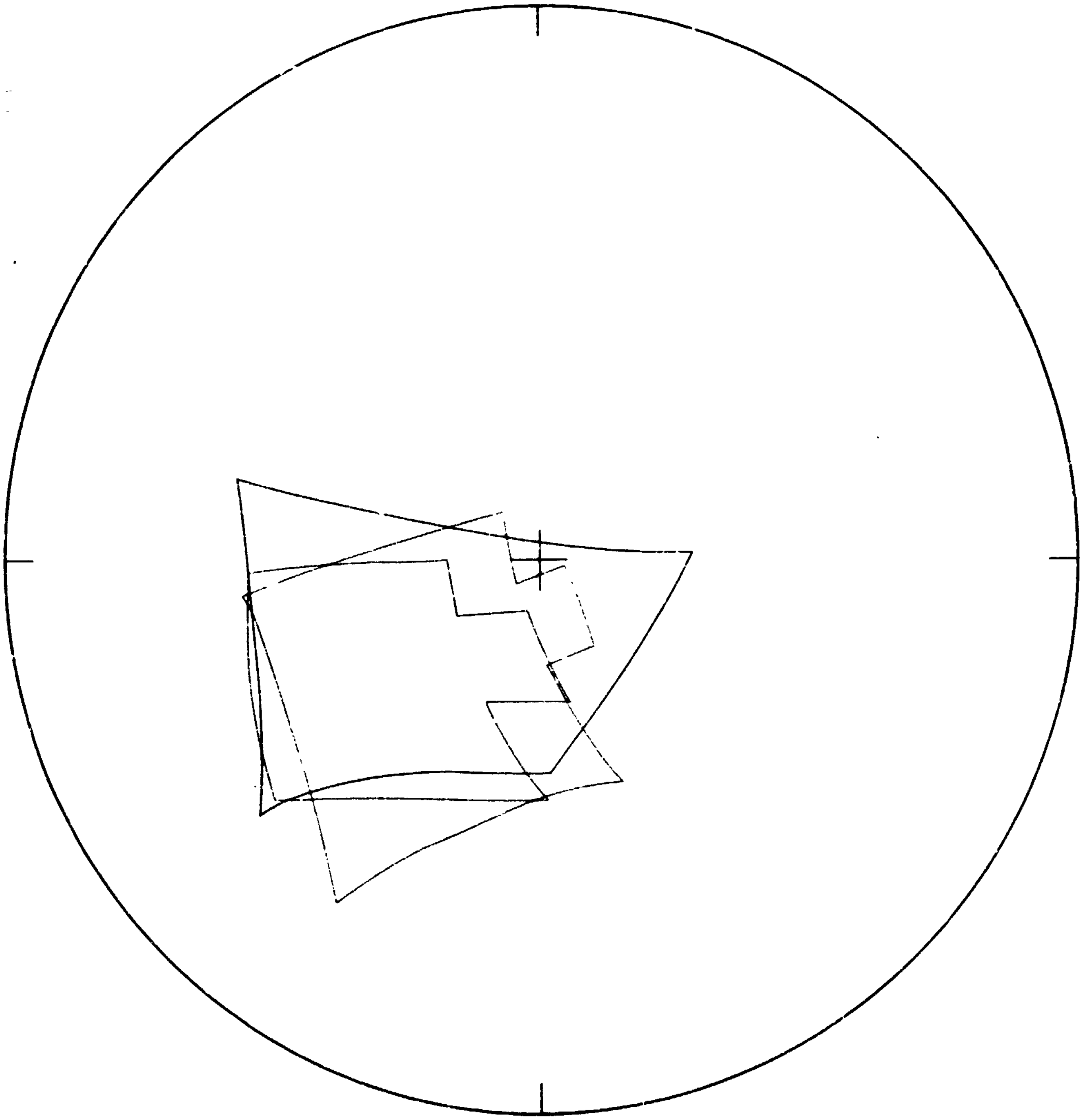
2.8 LUNAR PHOTOGRAPHIC INDICES

Index No.	Description
I(1)	Ranger Mission Photography
I(2)	Lunar Orbiter 80mm F.L. Vertical Photography
I(3)	Lunar Orbiter 80mm F.L. Oblique Photography
I(4)	Lunar Orbiter 610mm F.L. Vertical Photography
I(5)	Lunar Orbiter 610mm F.L. Oblique Photography
I(6)	Apollo Mission 8, 10, 12, 80mm F.L. Vertical Black and White Photography
I(6a)	Apollo Mission 15, 17, 60 and 80mm F.L. Vertical Black and White Photography
I(7)	Apollo Mission 8, 10, 12, 80mm F.L. Oblique Black and White Photography
I(8)	Apollo Mission 11, 12, 14, 80mm F.L. Oblique Black and White Photography
I(8a)	Apollo Mission 15, 17, 60mm F.L. Oblique Black and White Photography
I(8b)	Apollo Mission 15, 16, 17, 80 and 105mm F.L. Oblique Black and White Photography
I(9)	Apollo Mission 8, 11, 12, 14, 250 and 500mm F.L. Vertical Black and White Photography
I(9a)	Apollo Mission 15, 16, 17, 250 and 500mm F.L. Vertical Black and White Photography
I(10)	Apollo Mission 8, 10, 250mm F.L. Oblique Black and White Photography
I(11)	Apollo Mission 11, 12, 14, 250mm F.L. Oblique Black and White Photography
I(11a)	Apollo Mission 15, 16, 17, 250mm F.L. Oblique Black and White Photography
I(11b)	Apollo Mission 15 500mm F.L. Oblique Black and White Photography

Index No.	Description
I(12)	Apollo Mission 11, 12, 80mm F.L. Vertical Color Photography
I(12a)	Apollo Mission 15, 17, 60 and 80mm F.L. Vertical Color Photography
I(13)	Apollo Mission 10, 11, 12, 80mm F.L. Oblique Color Photography
I(13a)	Apollo Mission 15, 16, 17, 60 and 80mm F.L. Oblique Color Photography
I(14)	Apollo Mission 10, 14, 250mm F.L. Vertical Color Photography
I(14a)	Apollo Mission 15, 16, 17, 250mm F.L. Vertical Color Photography
I(15)	Apollo Mission 10, 14, 250mm F.L. Oblique Color Photography
I(15a)	Apollo Mission 15, 16, 17, 250mm F.L. Oblique Color Photography
I(16)	Apollo Mission 10, 14, 500mm F.L. Oblique Color Photography
I(17)	Apollo Mission 10, 14, 80mm F.L. Stereographic Black and White Photography
I(18)	Apollo Mission, 500mm and 18" F.L. Stereographic Black and White Photography
I(19)	Apollo Mission 15, 16, 17, 24" F.L. Panoramic Black and White Photography
I(20)	Apollo Mission 15, 16, 17, 3" F.L. Vertical Mapping Black and White Photography
I(21)	Apollo Mission 15, 16, 17, 3" F.L. Oblique Mapping Black and White Photography
I(22)	Apollo Mission 17 55mm F.L. Oblique Black and White Photography
II(1)	Lunar Orbiter, 80mm F.L. Vertical Black and White Photography
II(2)	Lunar Orbiter, 80mm F.L. Oblique Black and White Photography

Index No.	Description
II(3)	Lunar Orbiter, 610mm F.L. Vertical Black and White Photography
II(4)	Lunar Orbiter, 610mm F.L. Oblique Black and White Photography
II(5)	Apollo Mission 8, 10, 11, 12, 80mm F.L. Vertical Black and White Photography
II(6)	Apollo Mission 8, 10, 80mm F.L. Oblique Black and White Photography
II(7)	Apollo Mission 11, 14, 80mm F.L. Oblique Black and White Photography
II(7a)	Apollo Mission 15, 17, 60 and 80mm F.L. Oblique Black and White Photography
II(8)	Apollo Mission 10, 11, 250mm F.L. Vertical Black and White Photography
II(8a)	Apollo Mission 15, 16, 17, 250mm F.L. Vertical Black and White Photography
II(9)	Apollo Mission 8, 10, 250mm F.L. Oblique Black and White Photography
II(10)	Apollo Mission 11, 12, 250mm F.L. Oblique Black and White Photography
II(10a)	Apollo Mission 15, 16, 17, 250mm F.L. Oblique Black and White Photography
II(11)	Apollo Mission 10, 11, 12, 14, 80 and 60mm F.L. Oblique Color Photography
II(11a)	Apollo Mission 15, 17, 60 and 80mm F.L. Oblique Color Photography
II(11b)	Apollo Mission 17 60 and 80mm F.L. Vertical Color Photography
II(12)	Apollo Mission 8, 11, 13, 250mm F.L. Vertical Color Photography
II(12a)	Apollo Mission 15, 16, 17, 250mm F.L. Vertical Color Photography

Index No.	Description
II(13)	Apollo Mission 8, 10, 11, 12, 13, 250mm F.L. Oblique Color Photography
II(13a)	Apollo Mission 15, 16, 17, 250mm F.L. Oblique Color Photography
II(14)	Apollo Mission 14, 500mm F.L. Oblique Color Photography
II(15)	Apollo Mission 8, 10, 12, 14, 80mm F.L. Stereographic Black and White Photography
II(16)	Apollo Mission 15, 16, 17, 24" F.L. Panoramic Black and White Photography
II(17)	Apollo Mission 15, 16, 17, 3" F.L. Vertical Mapping Black and White Photography
II(18)	Apollo Mission 15, 16, 17, 3" F.L. Oblique Mapping Black and White Photography
II(19)	Apollo Mission 17 55mm F.L. Oblique Black and White and Color Photography



Earthside

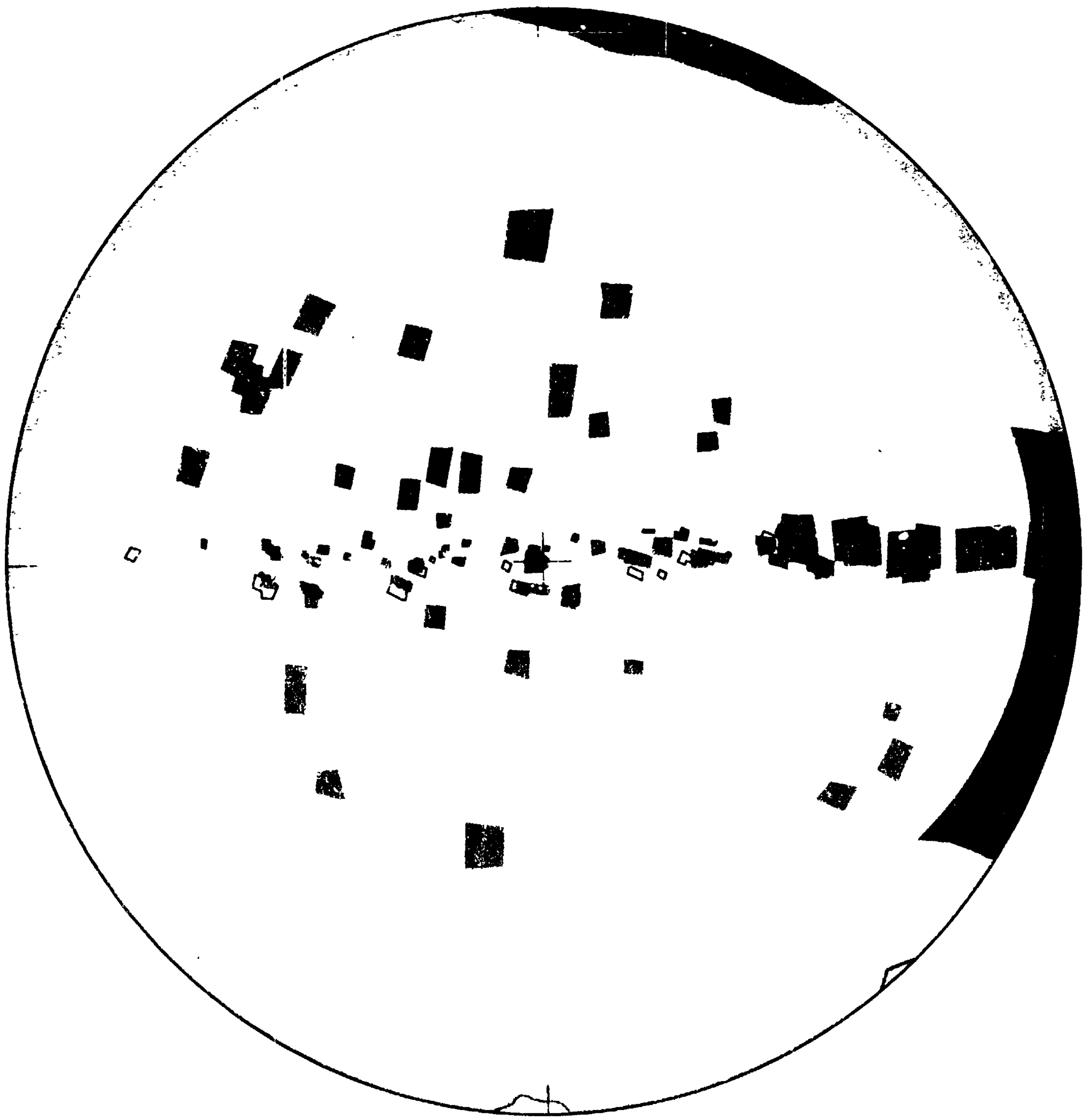
Ranger VII

Ranger VIII

Ranger IX

RANGER MISSION
25 & 75 mm F.L.
Oblique
B & W PHOTOGRAPHY

PHOTO INDEX NO. I (1)
Dec. 1971



Earthside

Orbiter I

Orbiter II

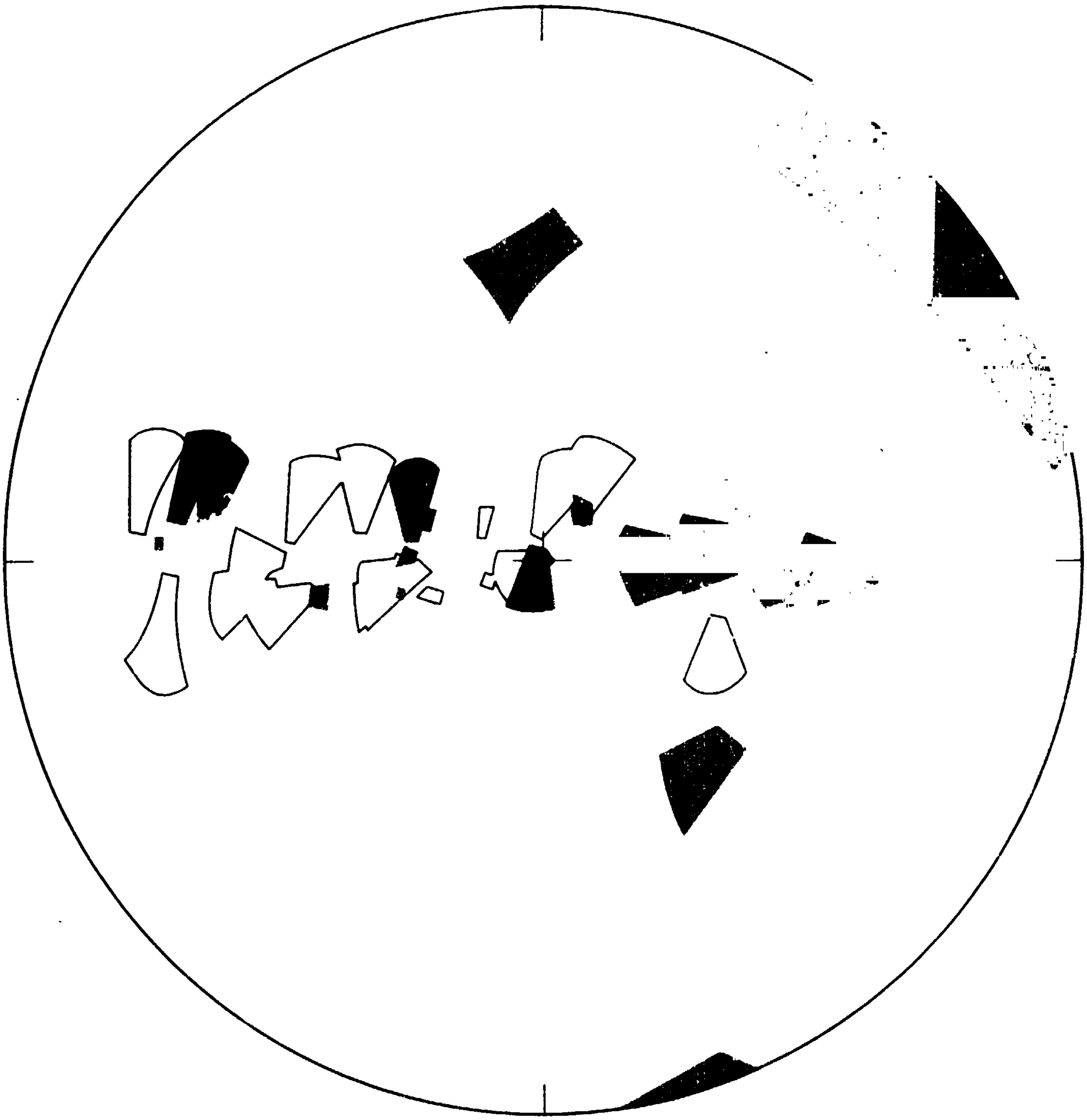
Orbiter III

Orbiter IV 99% Earthside coverage

Orbiter V

LUNAR ORBITER MISSION
80 mm F.L.
Near Vertical
B&W PHOTOGRAPHY

PHOTO INDEX NO. I (2)
Dec. 1971



Orbiter I

Orbiter II

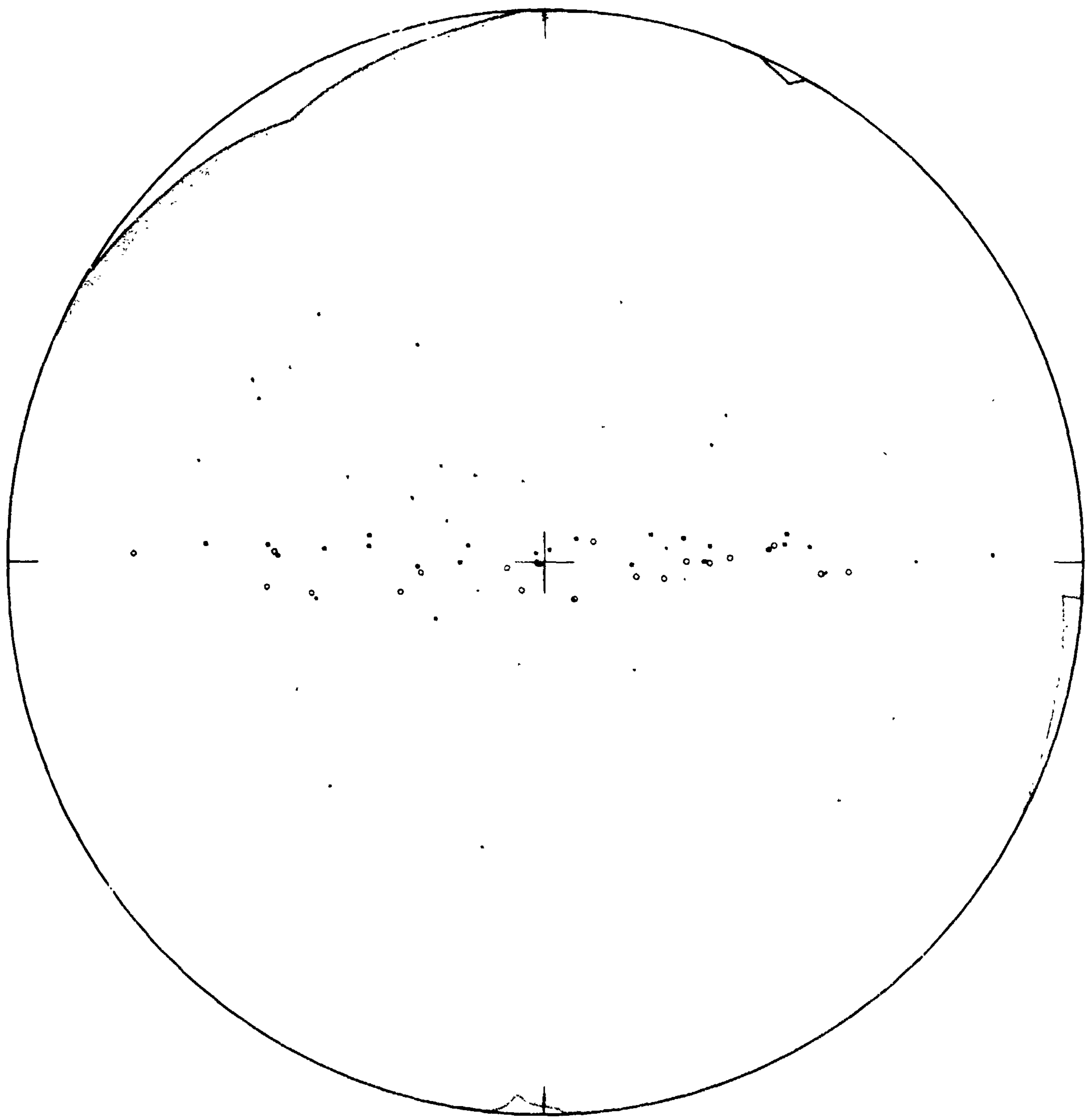
Orbiter III

Orbiter V

LUNAR ORBITER MISSION
80 mm F.L.
Oblique
B&W PHOTOGRAPHY

PHOTO INDEX NO. I (3)

Dec. 1971



Earthside

Orbiter I

Orbiter II

Orbiter III

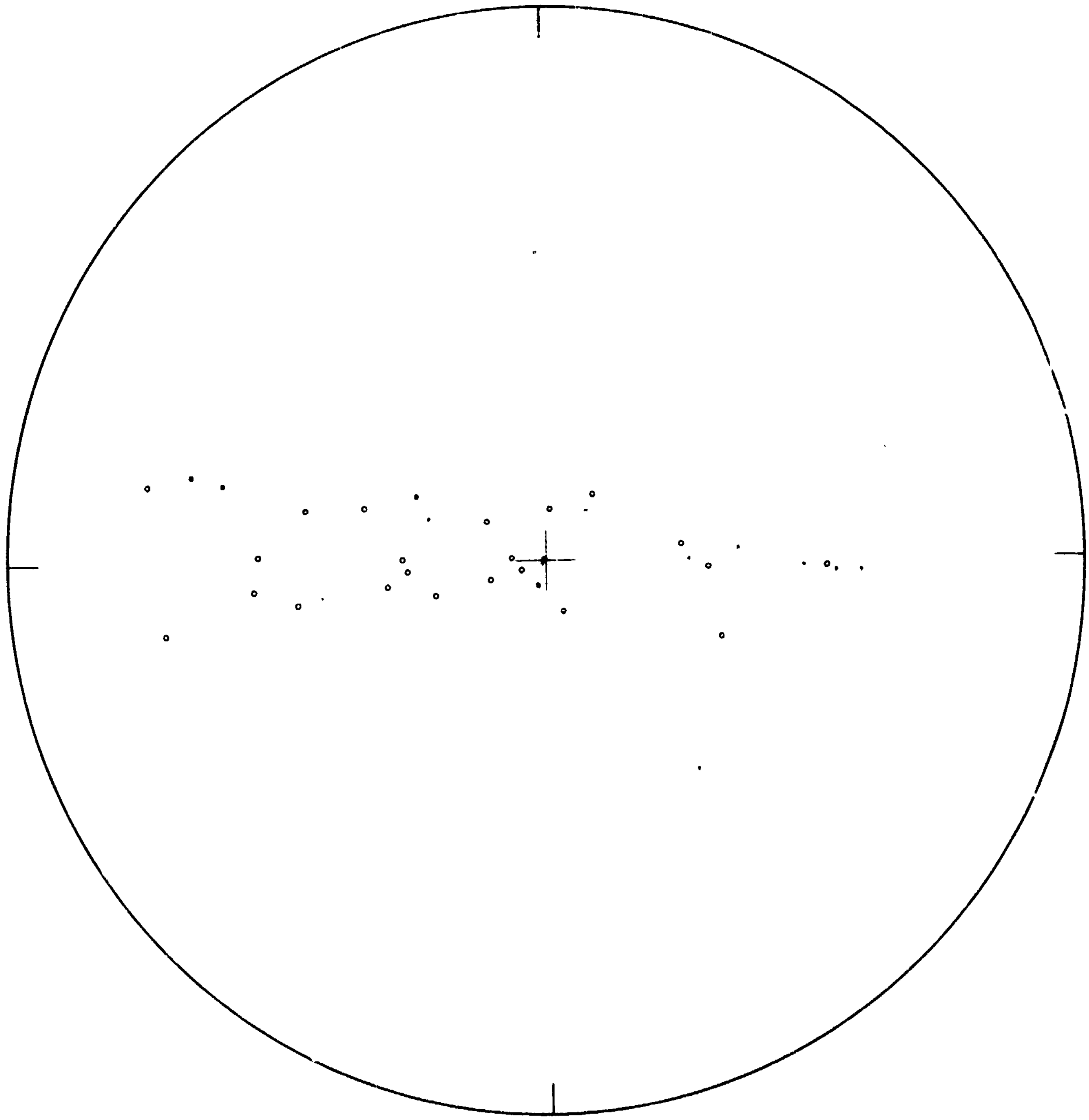
Orbiter IV

Orbiter V

LUNAR ORBITER MISSION
610 mm F.L.
Near Vertical
B&W PHOTOGRAPHY

PHOTO INDEX NO. I (4)

Dec. 1971



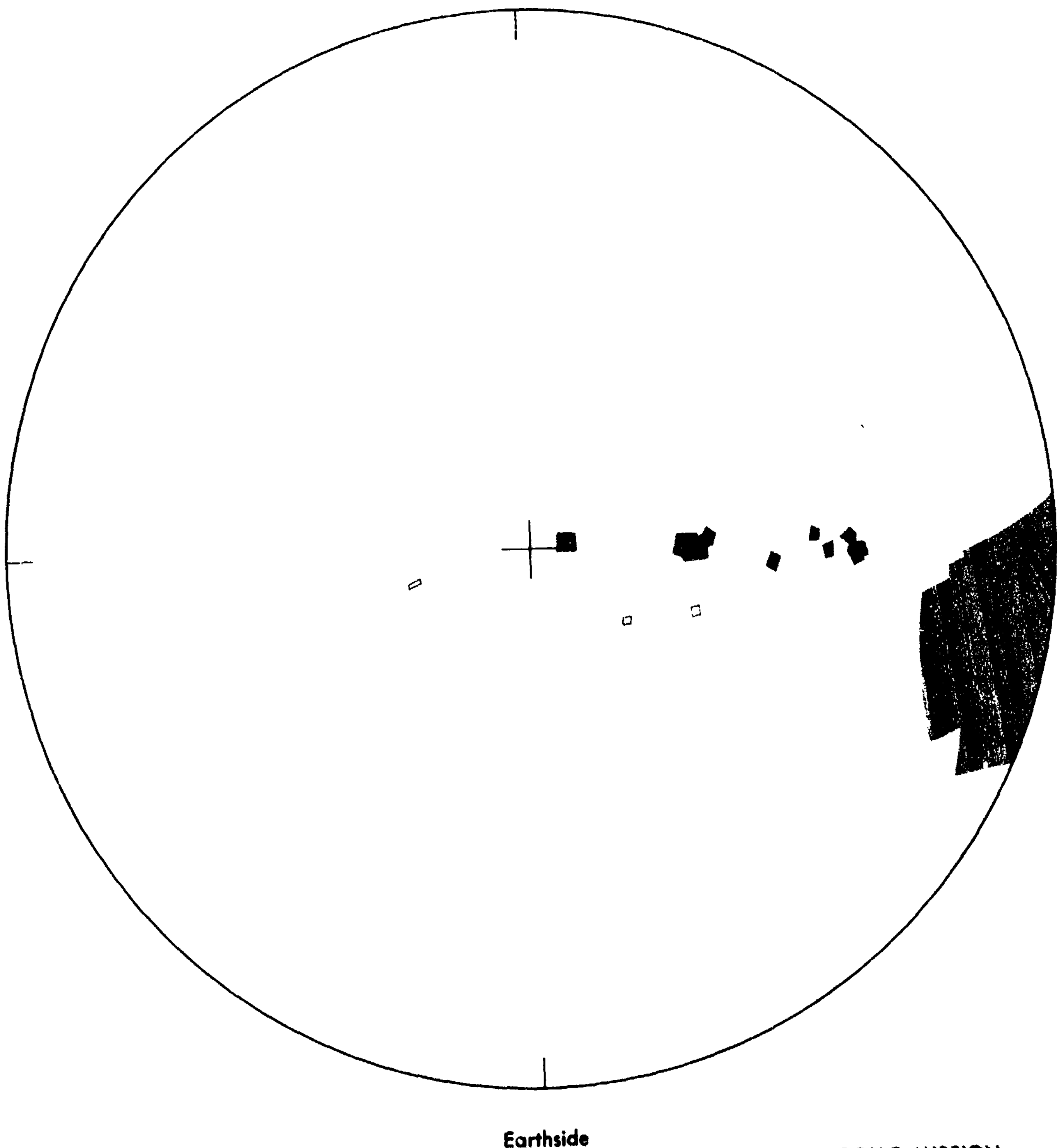
Earthside

LUNAR ORBITER MISSION
610 mm F.L.
Oblique
B&W PHOTOGRAPHY

Orbiter I
Orbiter III
Orbiter V

PHOTO INDEX NO. I (5)

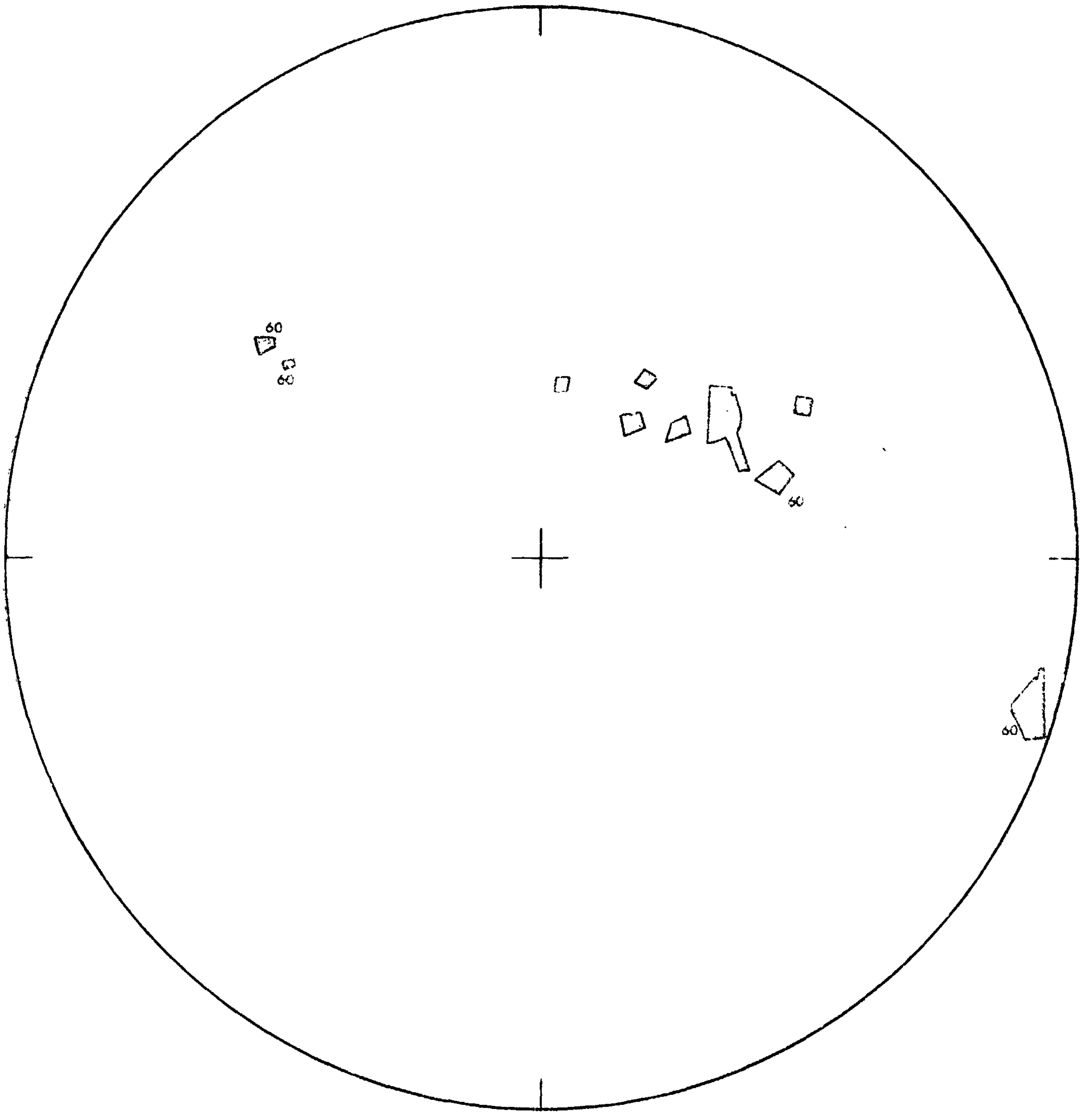
Dec. 1971



Apollo 8
Apollo 10
Apollo 12

APOLLO MISSION
80 mm F.L.
Near Vertical
B&W PHOTOGRAPHY

PHOTO INDEX NO I (6)
Dec. 1971

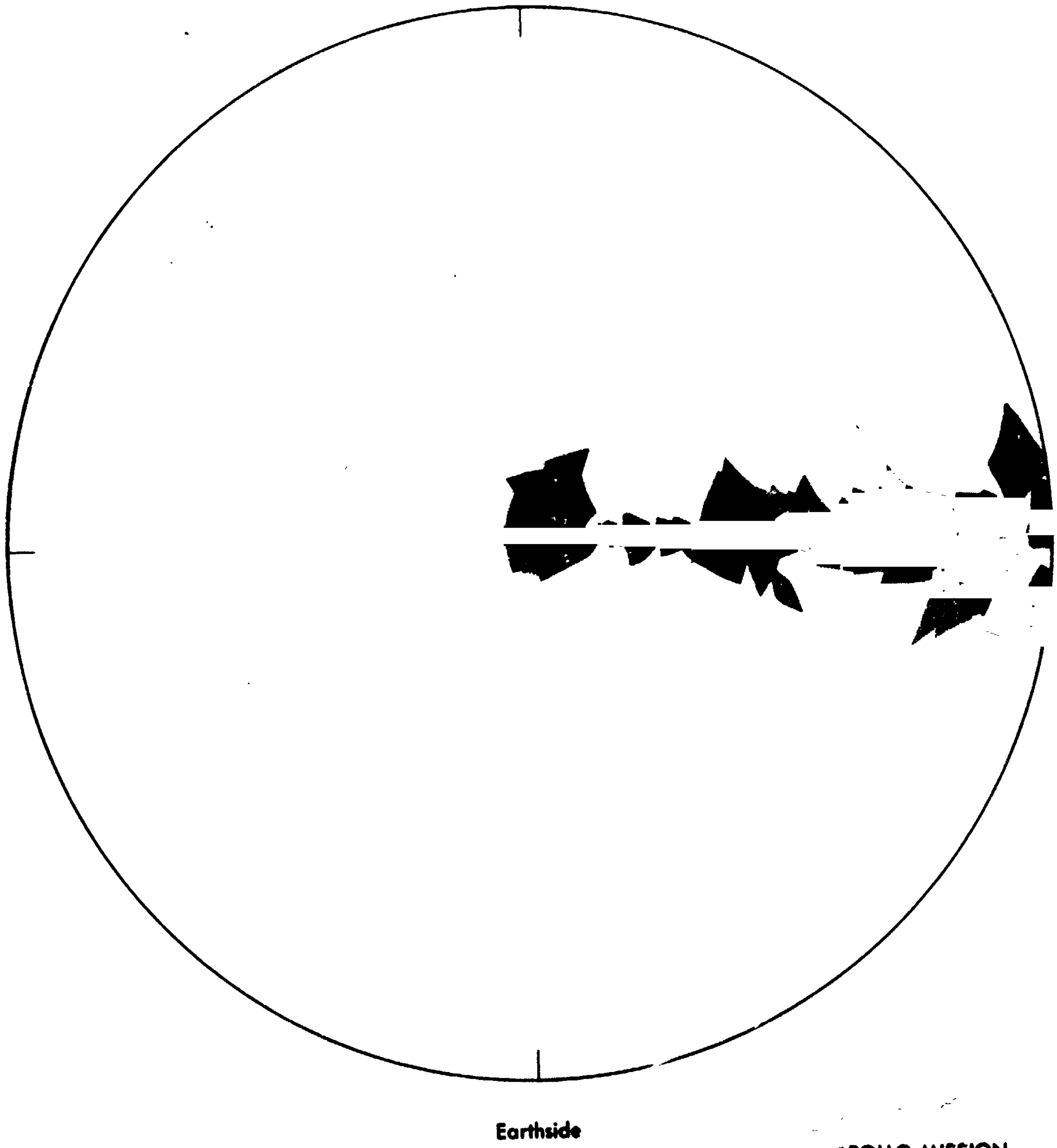


Earthside

APOLLO MISSION
80mm F.L. (60mm where noted)
Near Vertical
B&W PHOTOGRAPHY

Apollo 15
Apollo 17

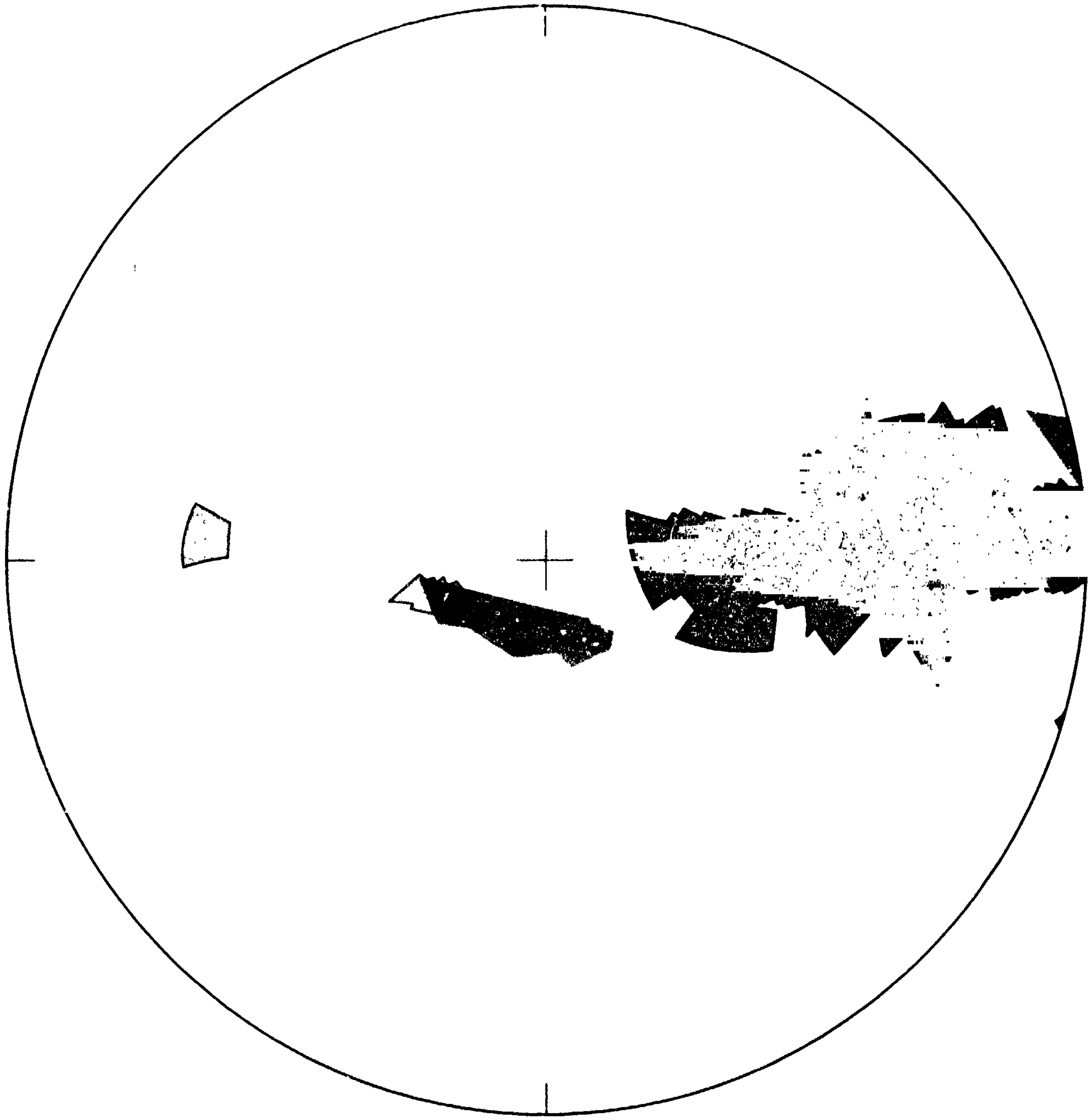
PHOTO INDEX NO. I (6a)
July 1974



APOLLO MISSION
80 mm F.L.
Oblique
B & W PHOTOGRAPHY

Apollo 8
Apollo 10

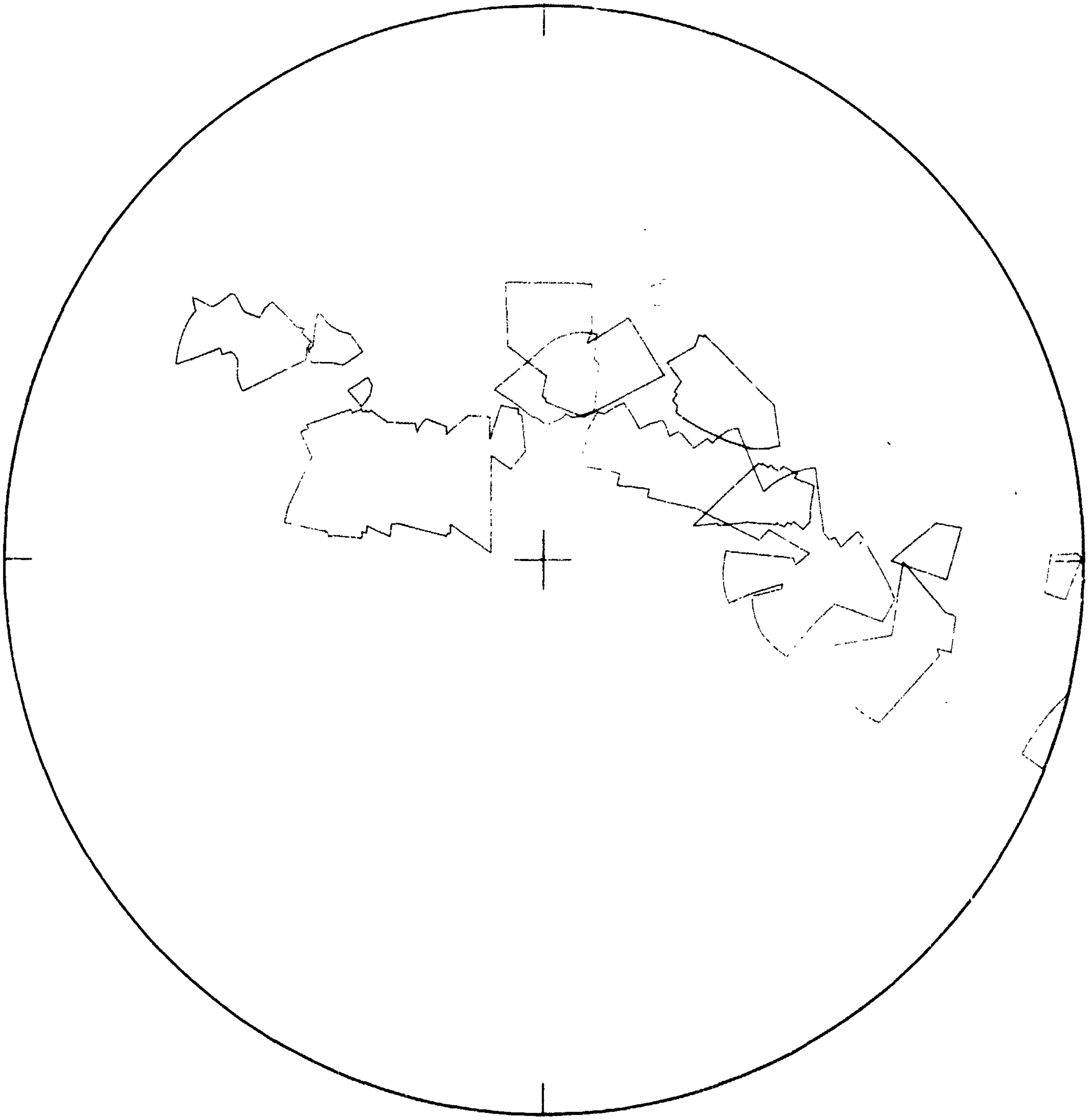
PHOTO INDEX NO. I (7)
Dec. 1971



Earthside

APOLLO MISSION
80 mm F.L.
Oblique
B & W PHOTOGRAPHY

PHOTO INDEX NO. I (@)
Dec. 1971



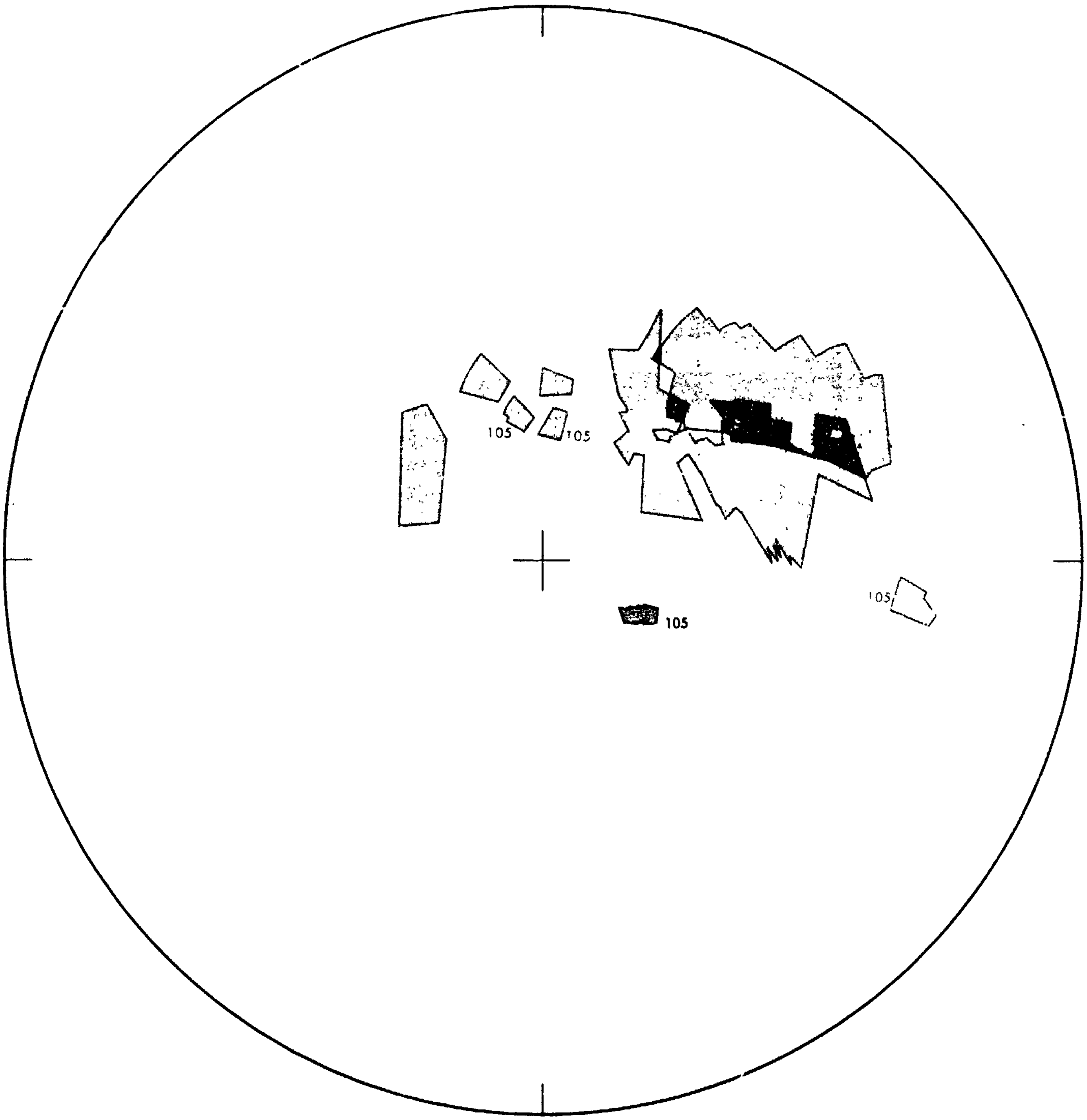
Earthside

APOLLO MISSION
60mm F.L.
Oblique
B&W PHOTOGRAPHY

Apollo 15 (solid box)
Apollo 17 (dashed box)

PHOTO INDEX NO. I (8a)

July 1974



Earthside

Apollo 15

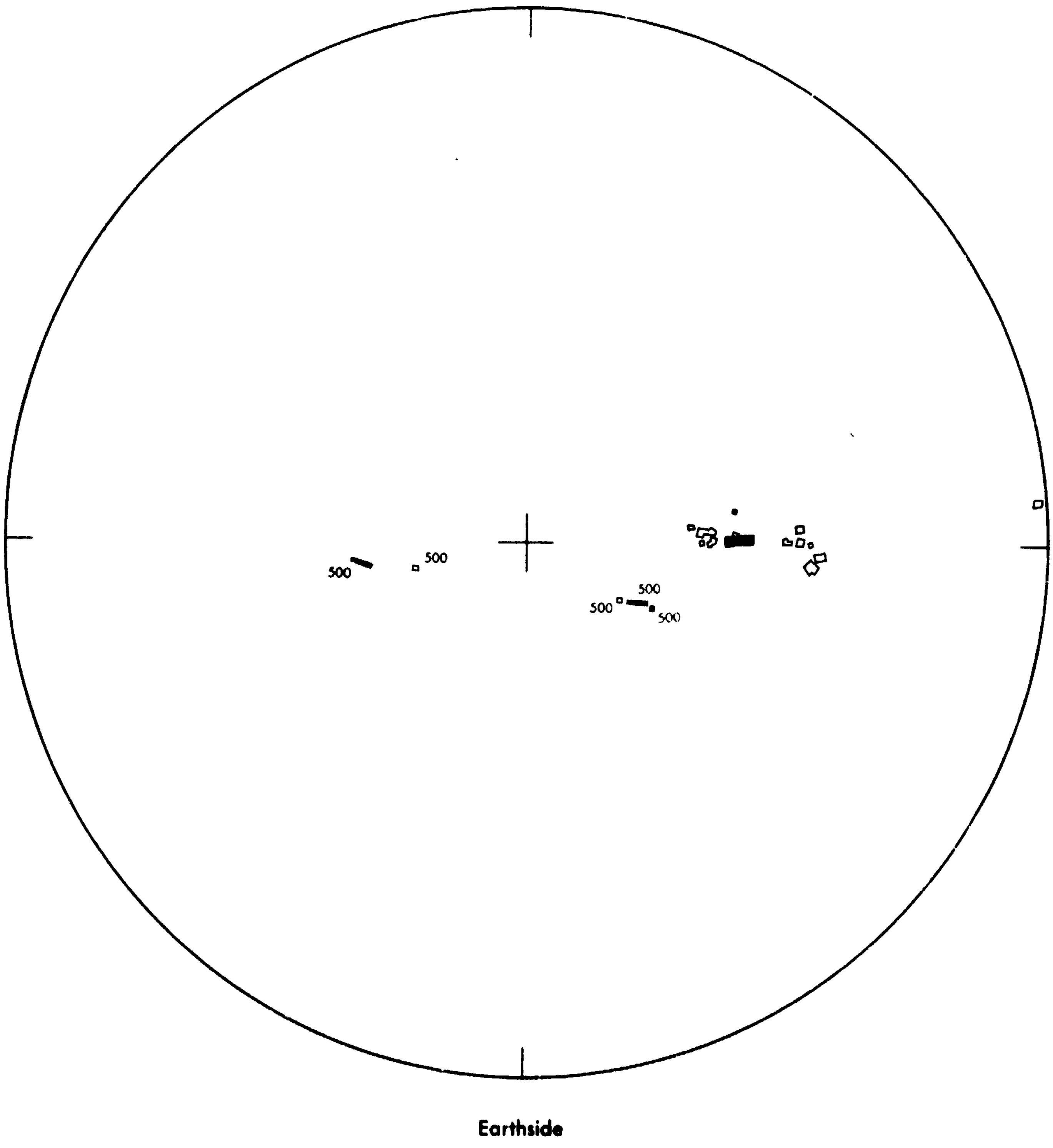
Apollo 16

Apollo 17

APOLLO MISSION
80mm F.L. (105mm where noted)
Oblique
B&W PHOTOGRAPHY

PHOTO INDEX NO. I (8b)

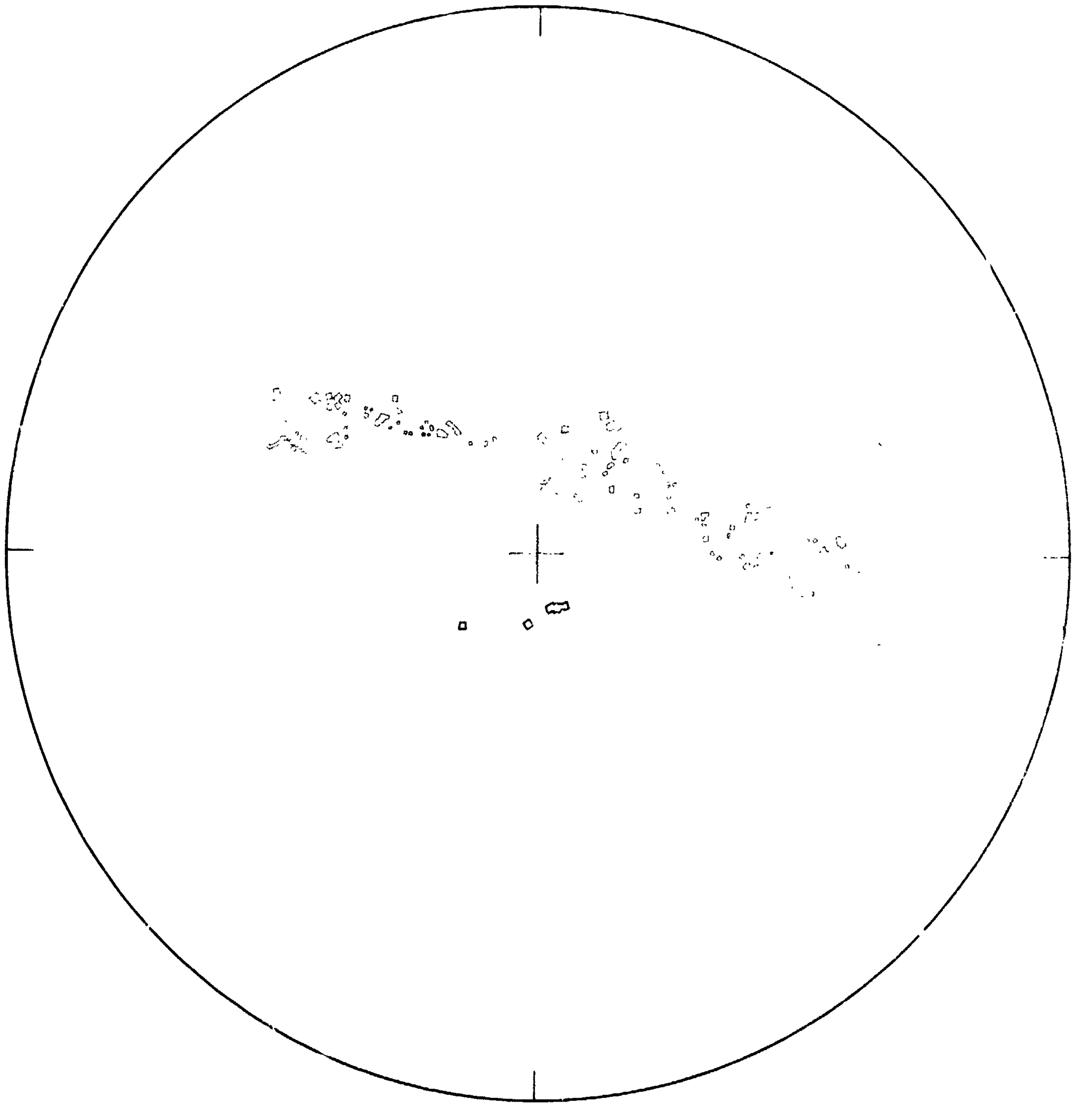
July 1974



Apollo 8
Apollo 11
Apollo 12
Apollo 14

APOLLO MISSION
250 mm F.L. (500 mm where noted)
Near Vertical
B & W PHOTOGRAPHY

PHOTO INDEX NO. I (9)
Dec. 1971



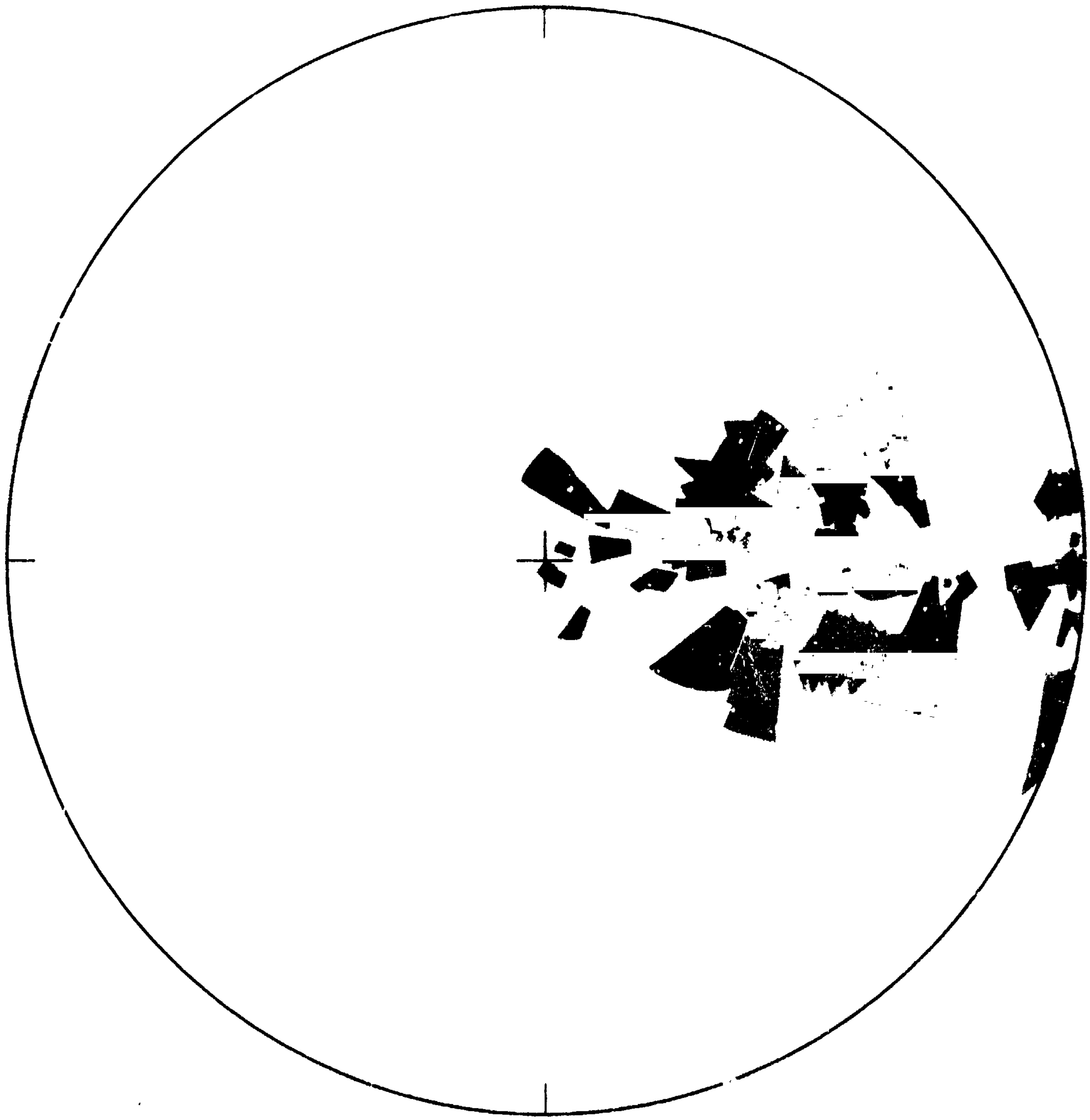
Earthside

APOLLO MISSION
250 mm F.L. (500 mm where noted)
Near Vertical
B&W PHOTOGRAPHY

Apollo 15
Apollo 16
Apollo 17

PHOTO INDEX NO. I (9a)

July 1974



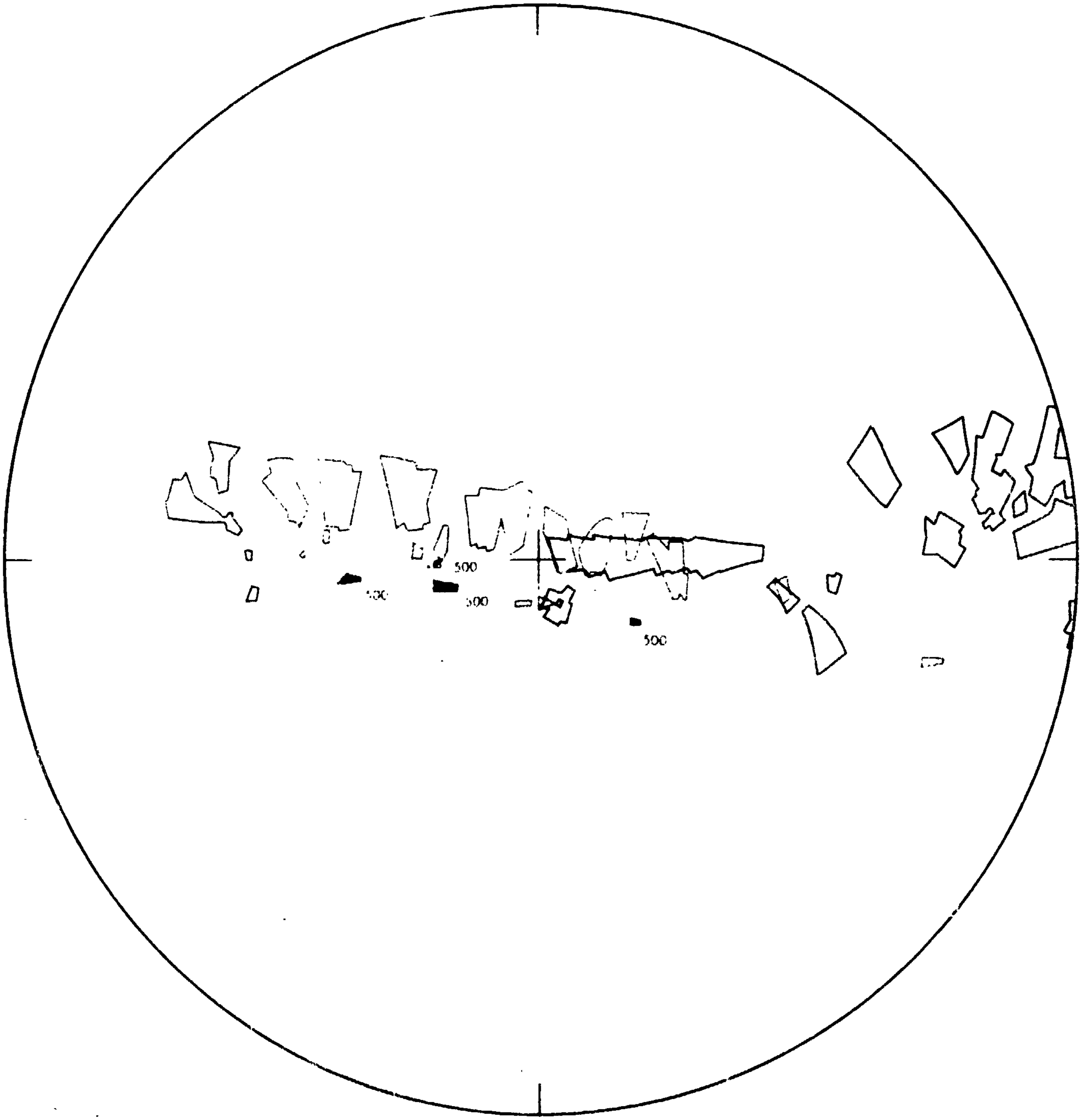
Earthside

APOLLO MISSION
250 mm F.L.
Oblique
B & W PHOTOGRAPHY

Apollo 8
Apollo 10

PHOTO INDEX NO. I ([illegible])

[illegible] 1971



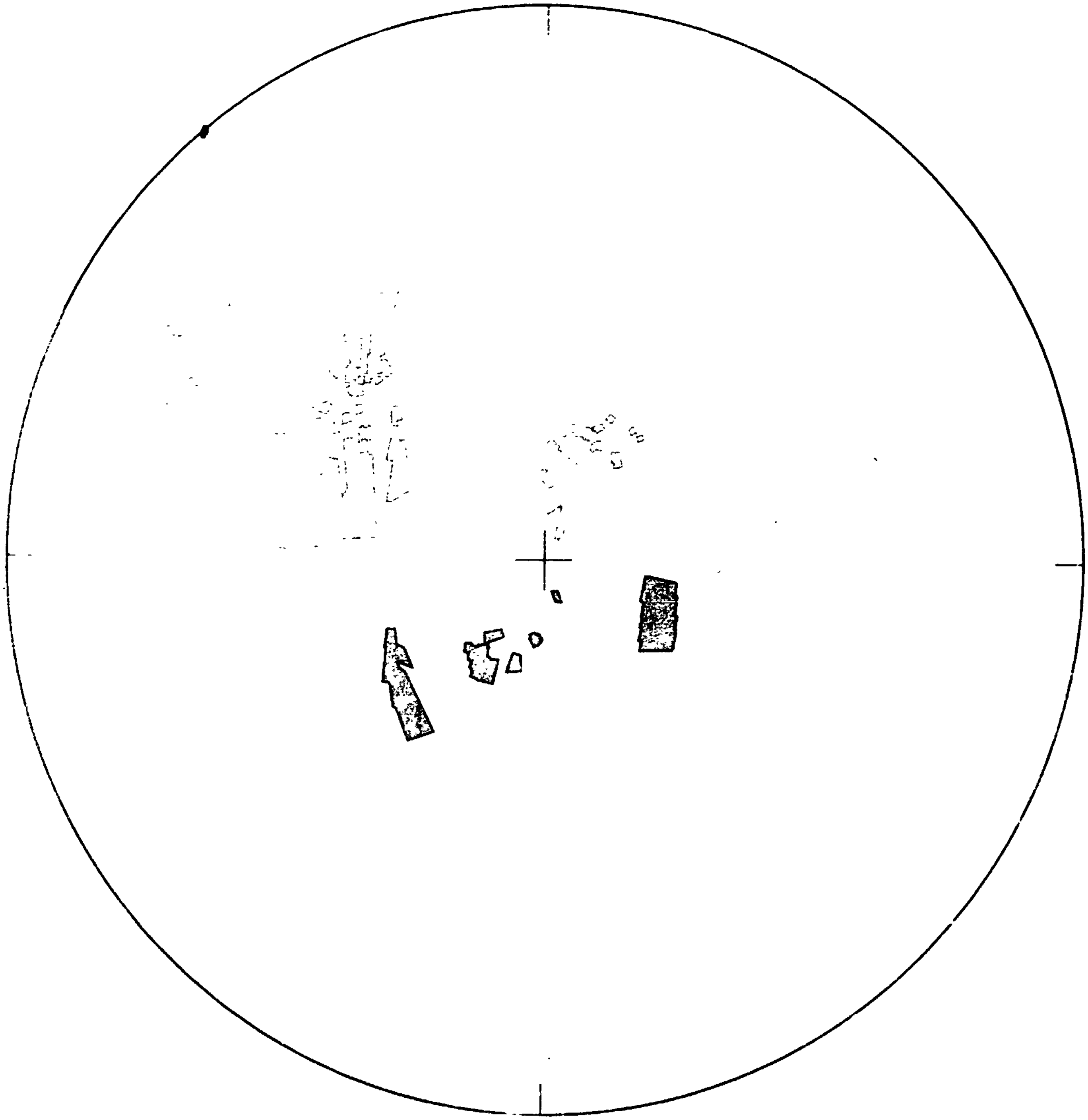
Earthside

APOLLO MISSION
250 mm F.L. (500 mm where noted)
Oblique
B & W PHOTOGRAPHY

Apollo 11
Apollo 12 500
Apollo 14

PHOTO INDEX NO. I (11)

Dec. 1971



Earthside

Apollo 15

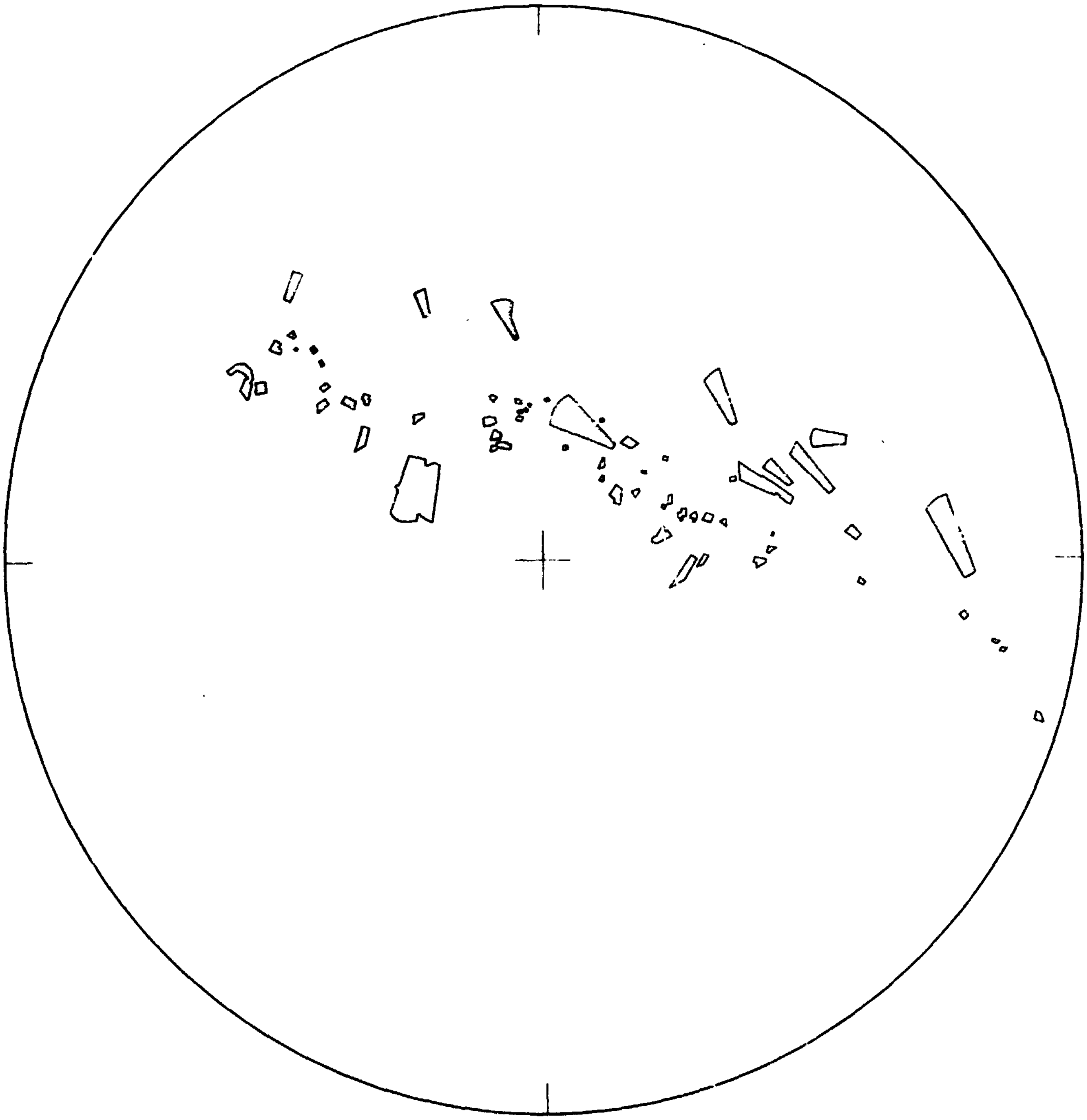
Apollo 16

Apollo 17

APOLLO MISSION
250mm F.L.
Oblique
B&W PHOTOGRAPHY

PHOTO INDEX NO. I (11a)

July 1974

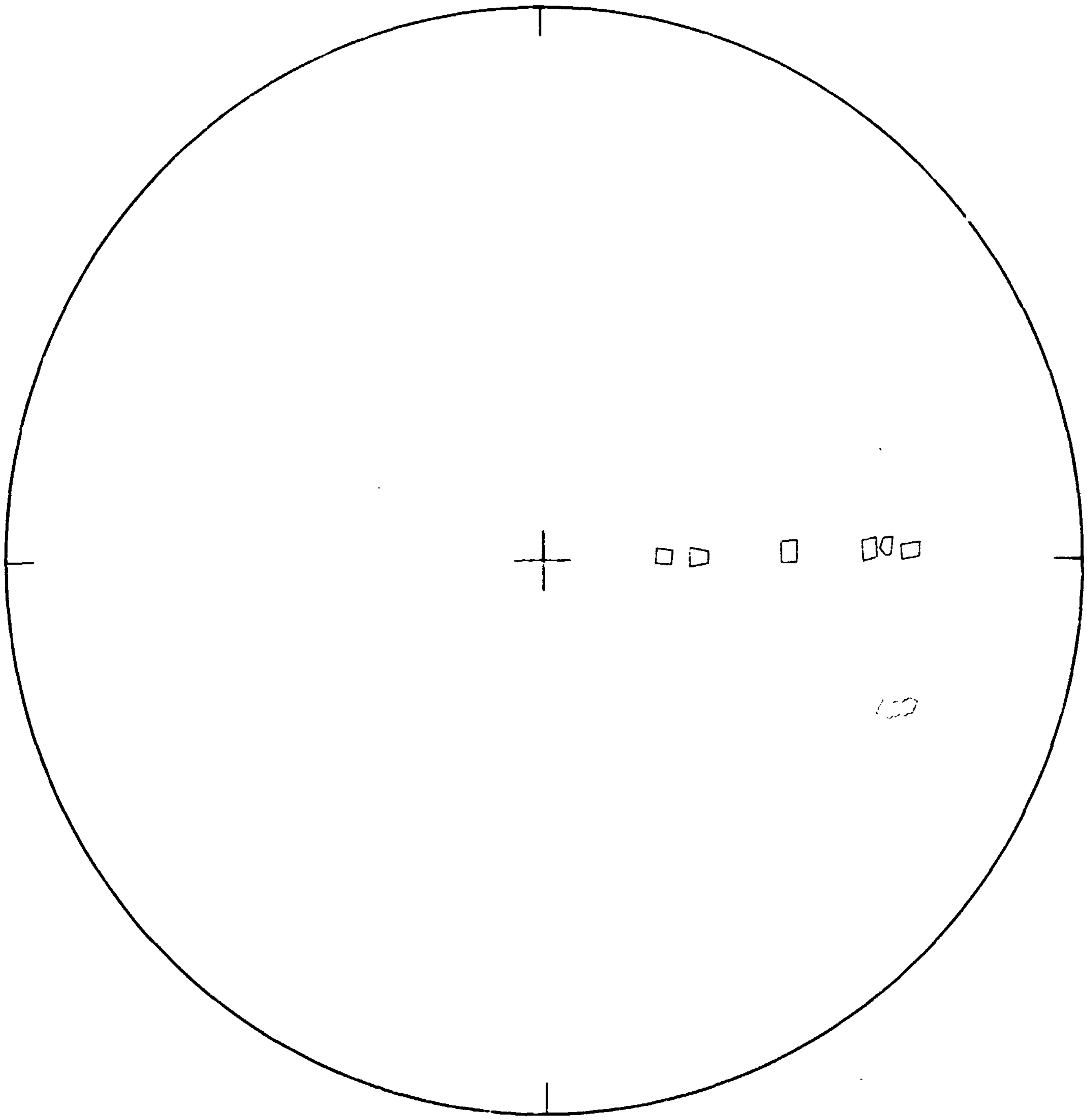


Earthside

APOLLO MISSION
500mm F.L.
Oblique
B&W PHOTOGRAPHY

Apollo 15 ☐

PHOTO INDEX NO. I (11-b)
Aug. 1972



Earthside

APOLLO MISSION
80 mm F.L.
Near Vertical
COLOR PHOTOGRAPHY

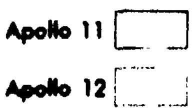
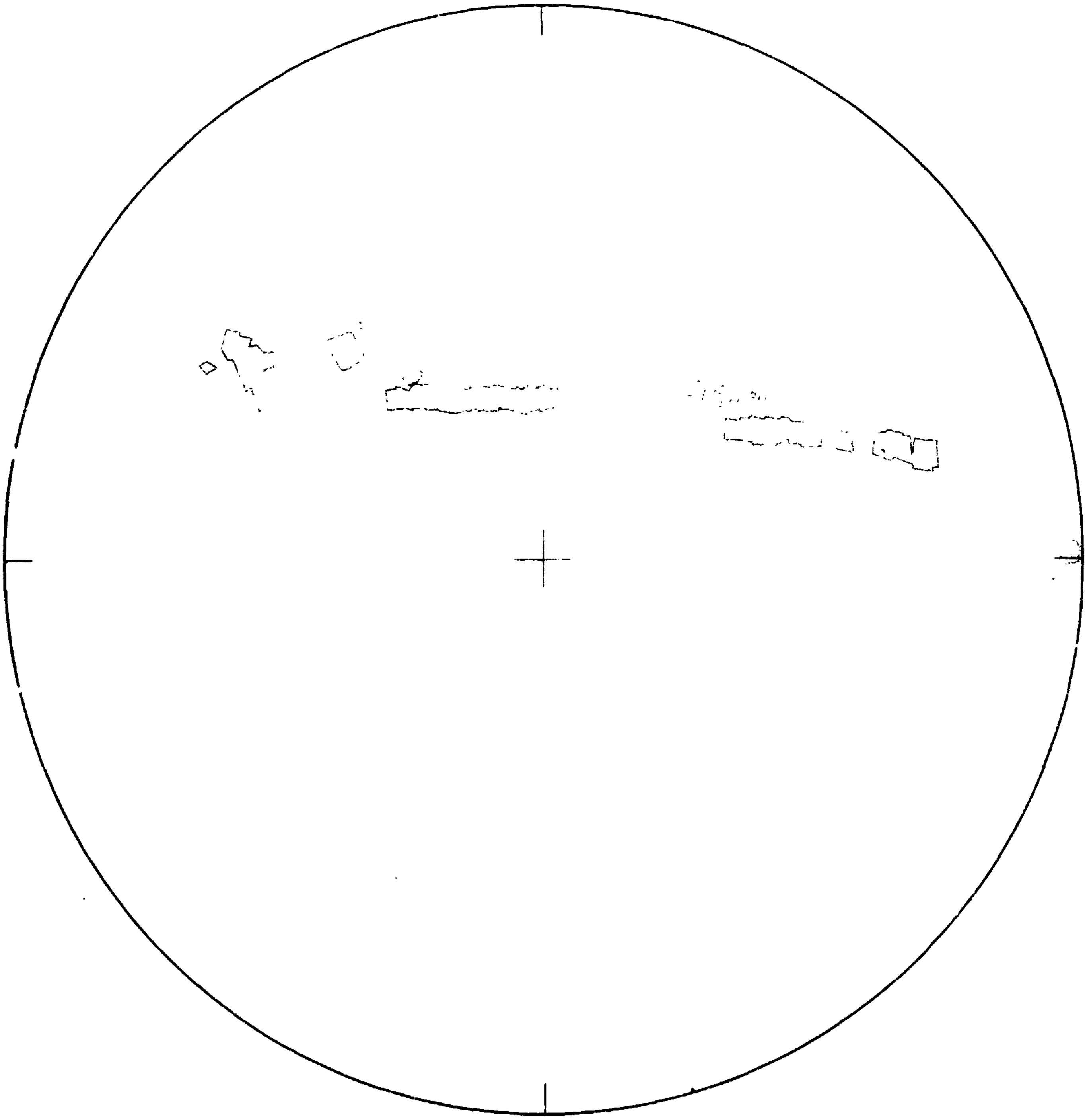


PHOTO INDEX NO. I (12)

Dec. 1971



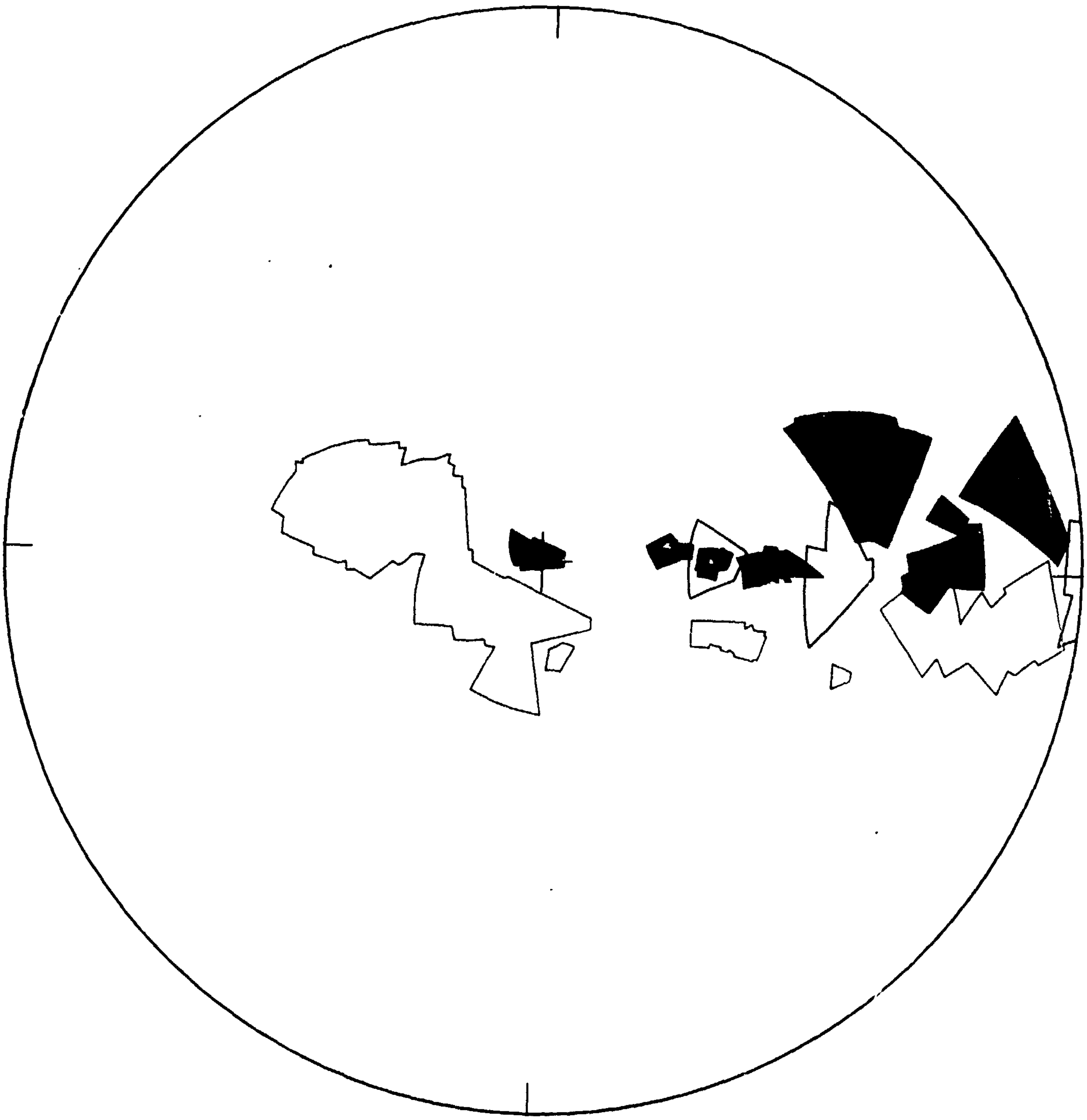
Earthside

APOLLO MISSION
80mm F.L. (60mm where noted)
Near Vertical
COLOR PHOTOGRAPHY

Apollo 15

Apollo 17

PHOTO INDEX NO. I (12a)
July 1974

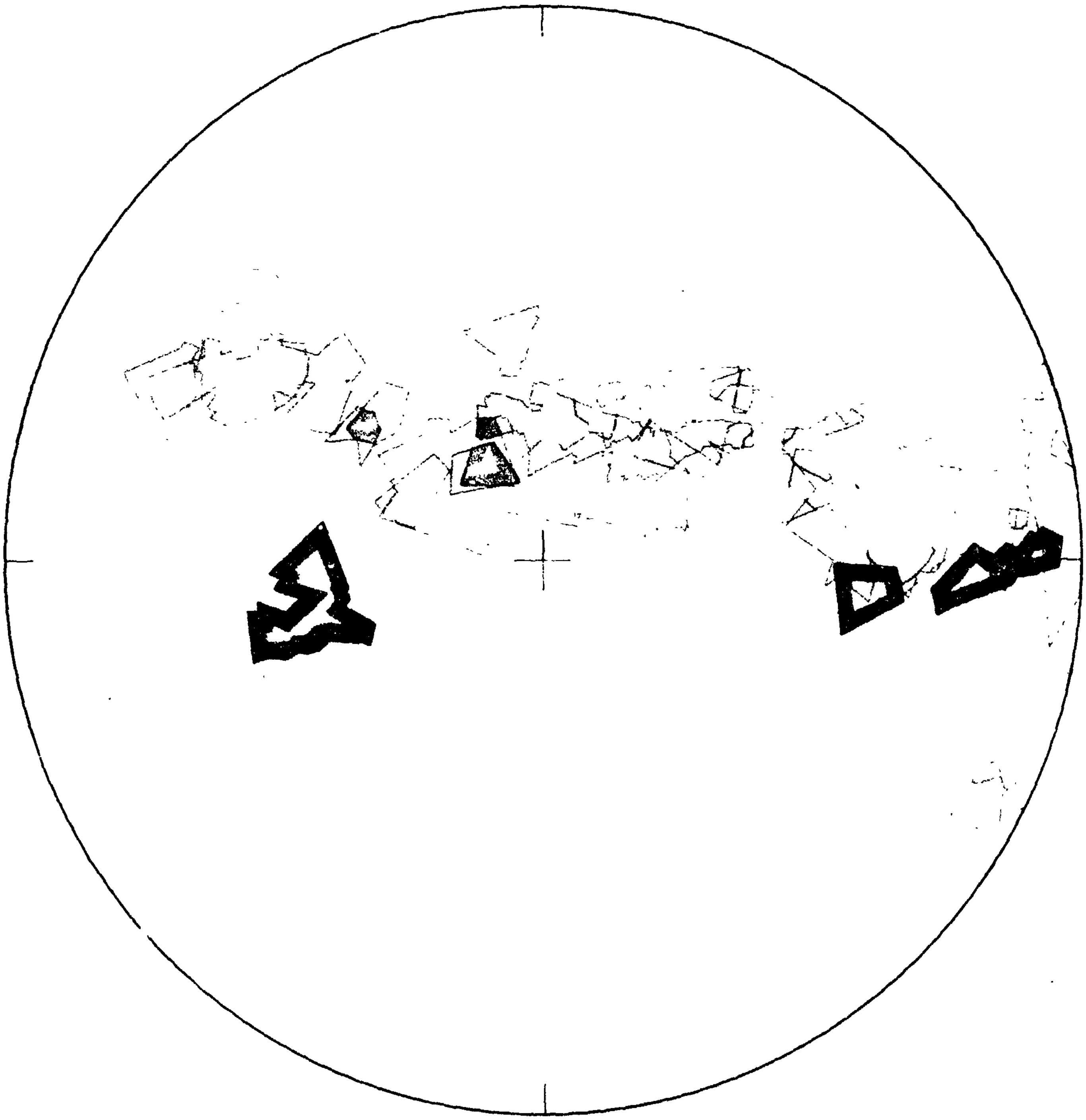


Earthside

Apollo 10 ■
Apollo 11 □
Apollo 12 □

APOLLO MISSION
80 mm F.L.
Oblique
COLOR PHOTOGRAPHY

PHOTO INDEX NO. I (13)
Dec. 1971



Earthside

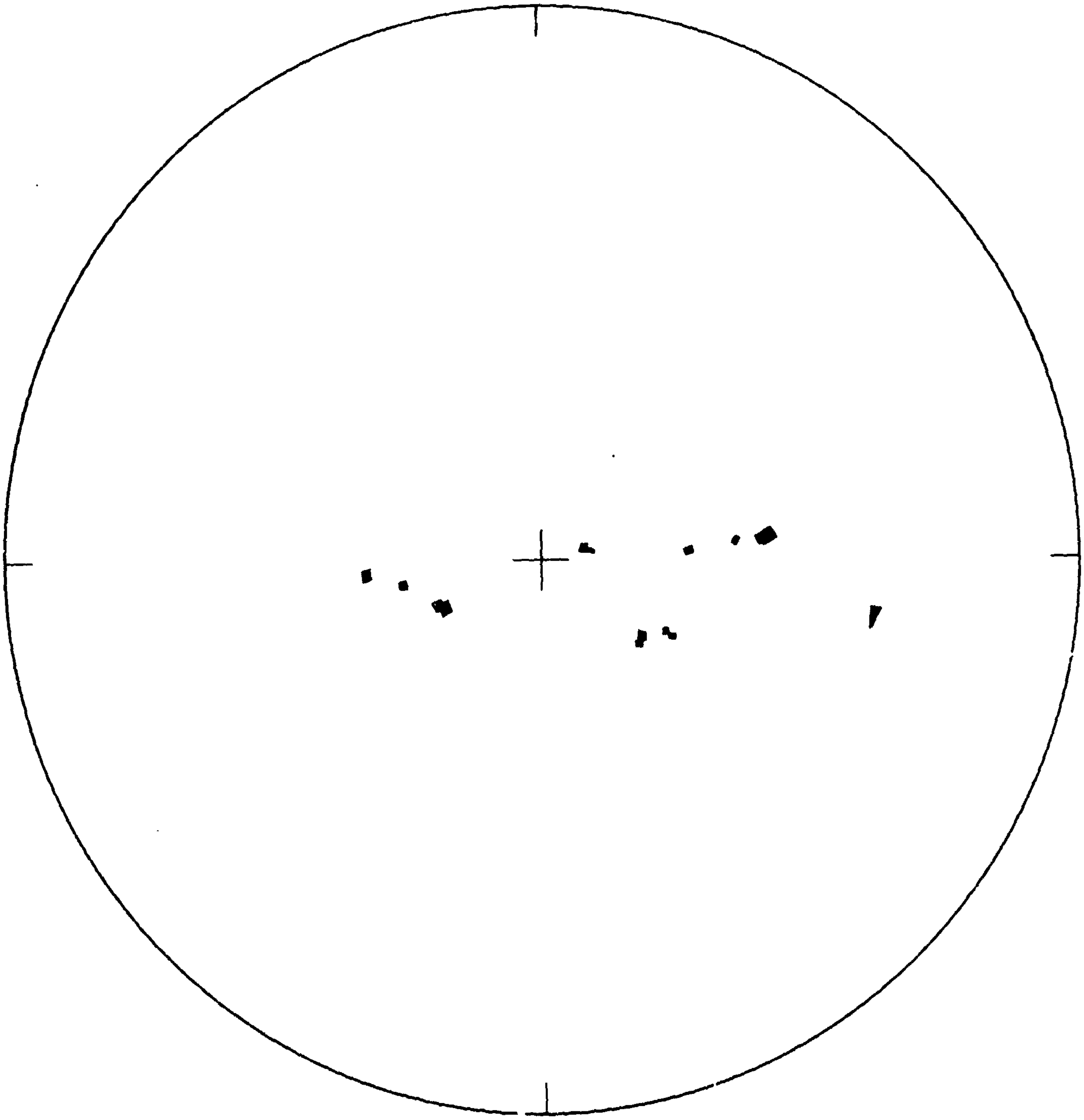
Apollo 15

Apollo 16 80

Apollo 17

APOLLO MISSION
60&80mm F.L.
Oblique
COLOR PHOTOGRAPHY

PHOTO INDEX NO. I (13a)
July 1974

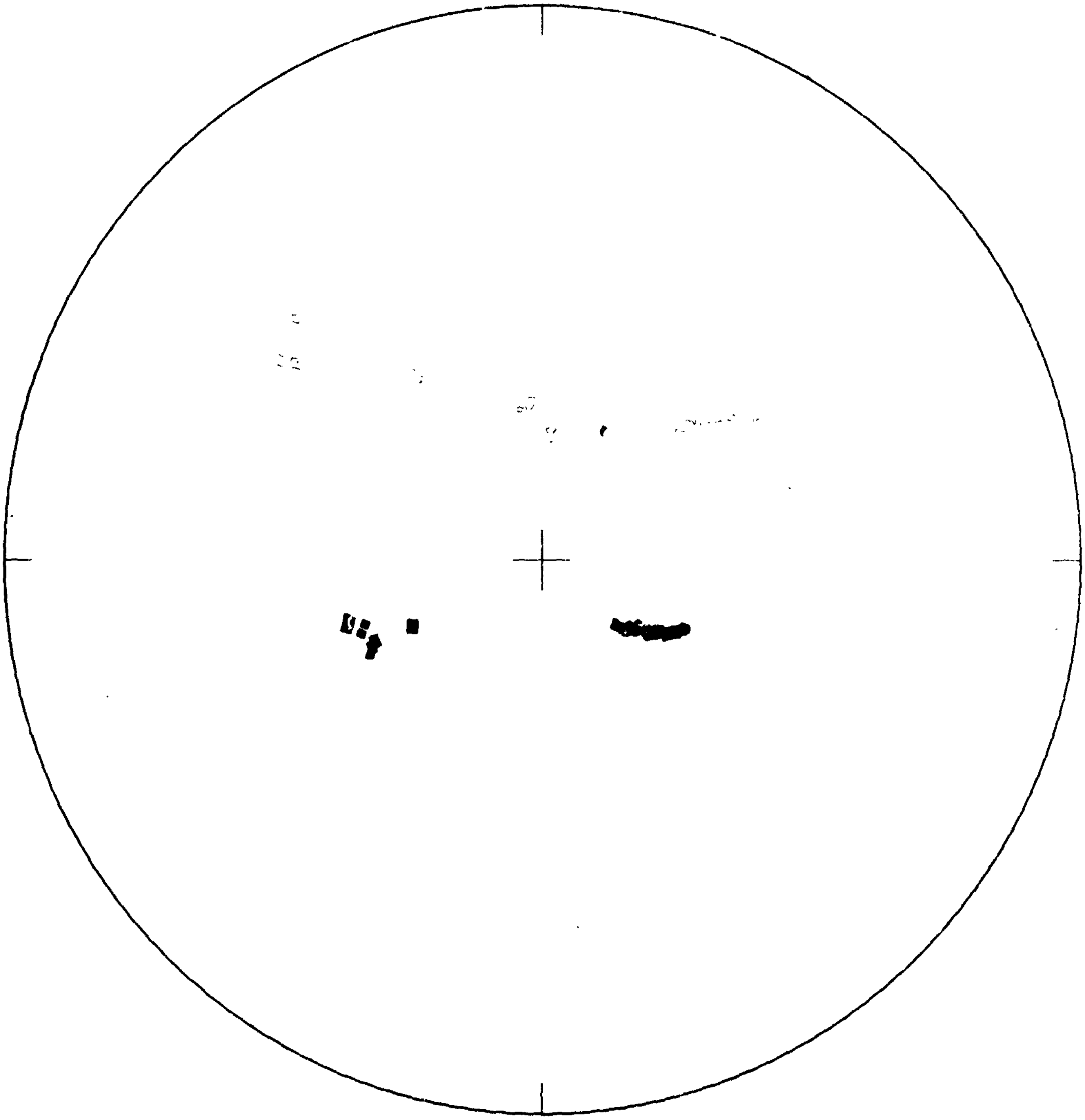


Earthside

APOLLO MISSION
250 mm F.L.
Near Vertical
COLOR PHOTOGRAPHY

Apollo 10
Apollo 14

PHOTO INDEX NO. I (14)
Dec. 1971



Earthside

Apollo 15

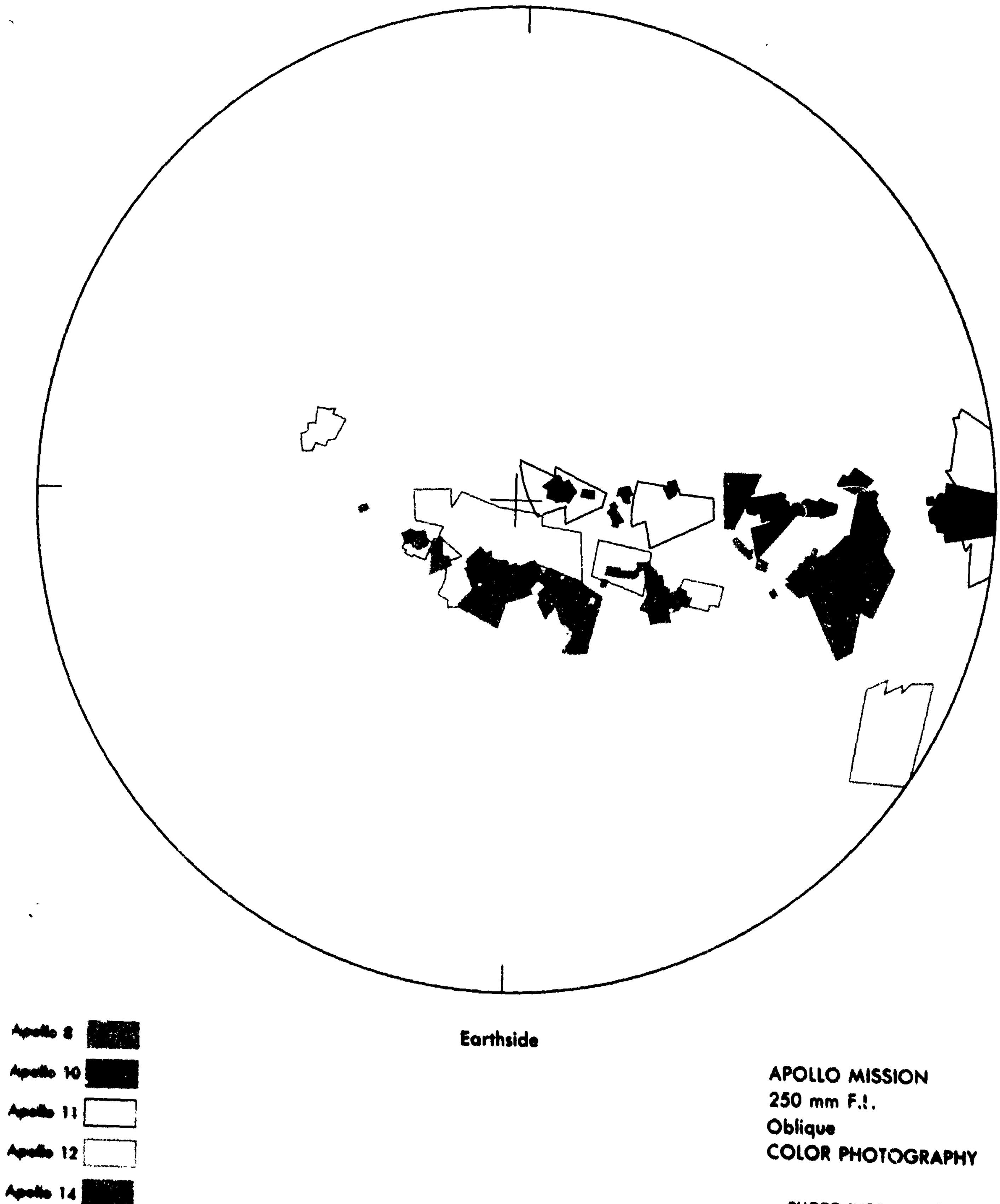
Apollo 16

Apollo 17

APOLLO MISSION
250mm F.L.
Near Vertical
COLOR PHOTOGRAPHY

PHOTO INDEX NO. I (14a)

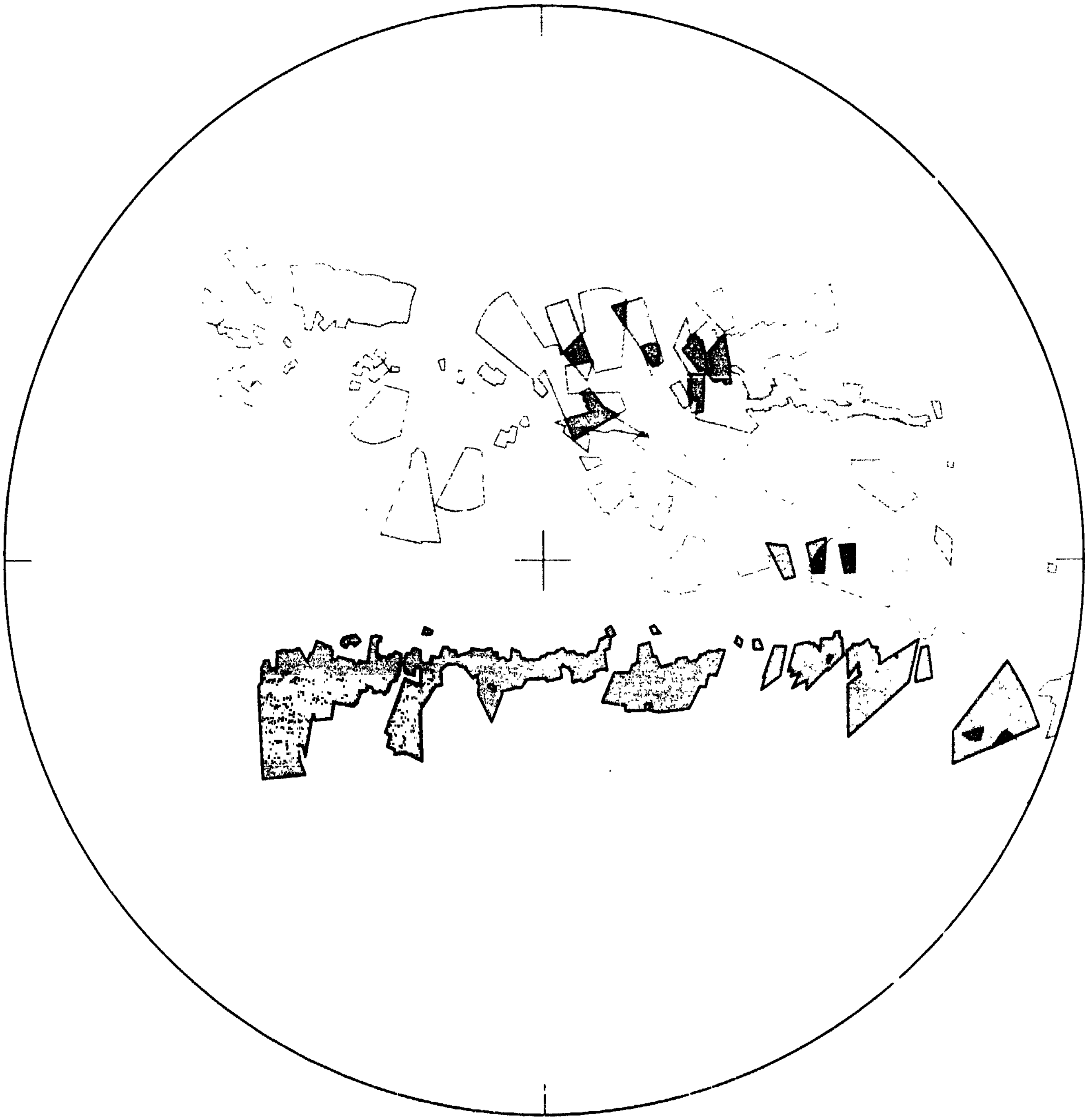
July 1974



APOLLO MISSION
250 mm F.L.
Oblique
COLOR PHOTOGRAPHY

PHOTO INDEX NO. I (15)

Dec. 1971

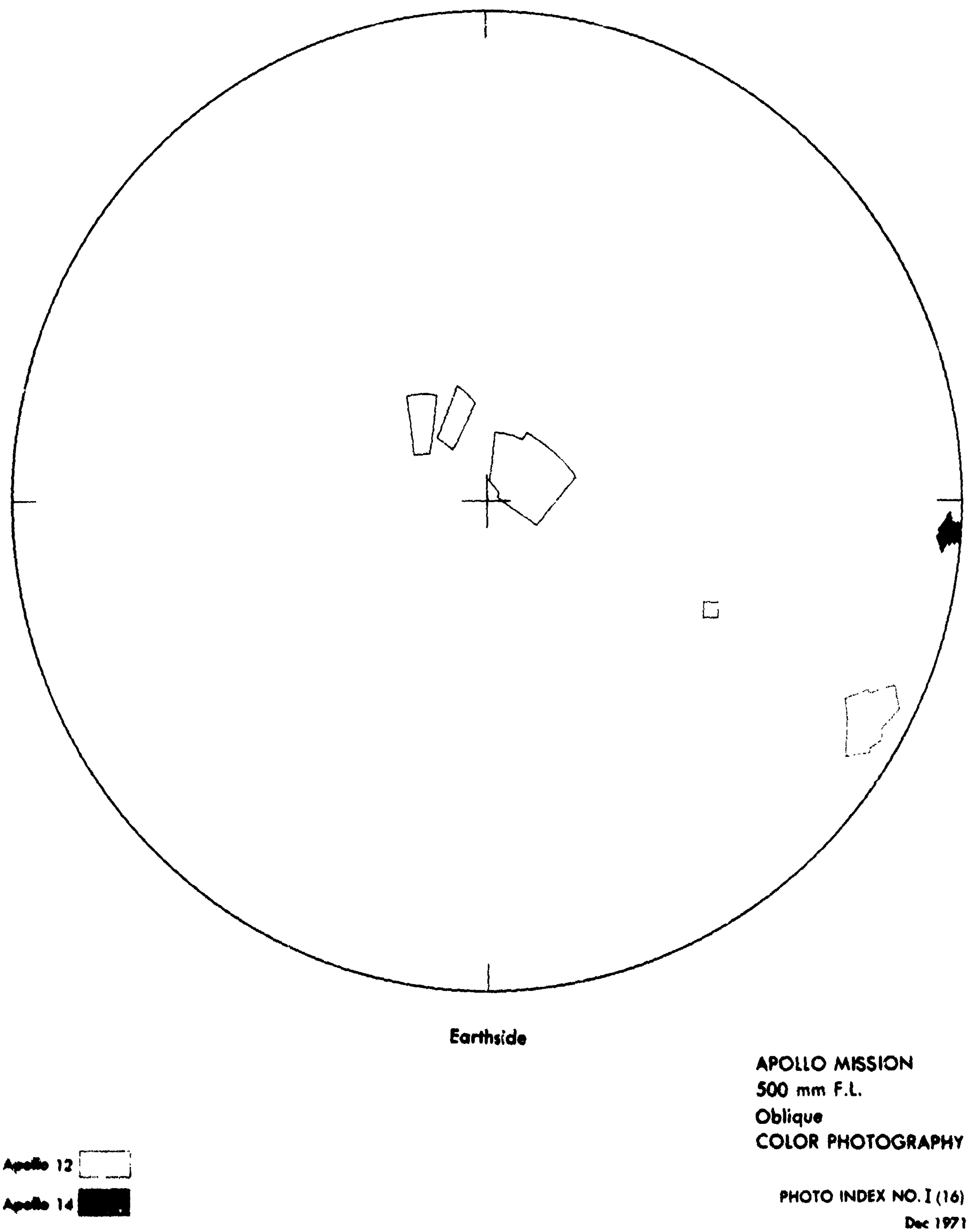


Earthside

APOLLO MISSION
250mm F.L.
Oblique
COLOR PHOTOGRAPHY

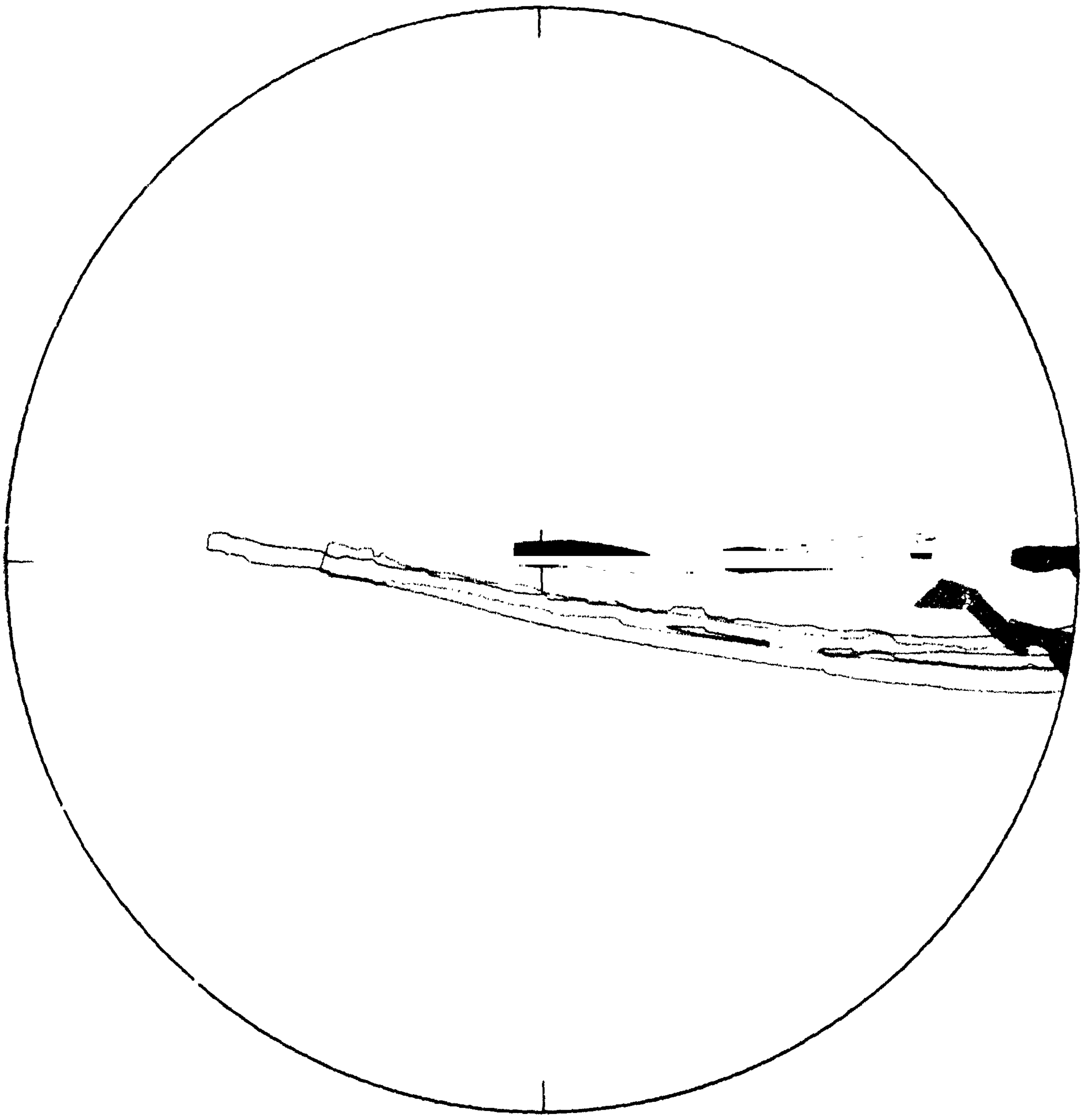
Apollo 15
Apollo 16
Apollo 17

PHOTO INDEX NO. I (15a)
July 1974



APOLLO MISSION
500 mm F.L.
Oblique
COLOR PHOTOGRAPHY

PHOTO INDEX NO. I (16)
Dec 1971



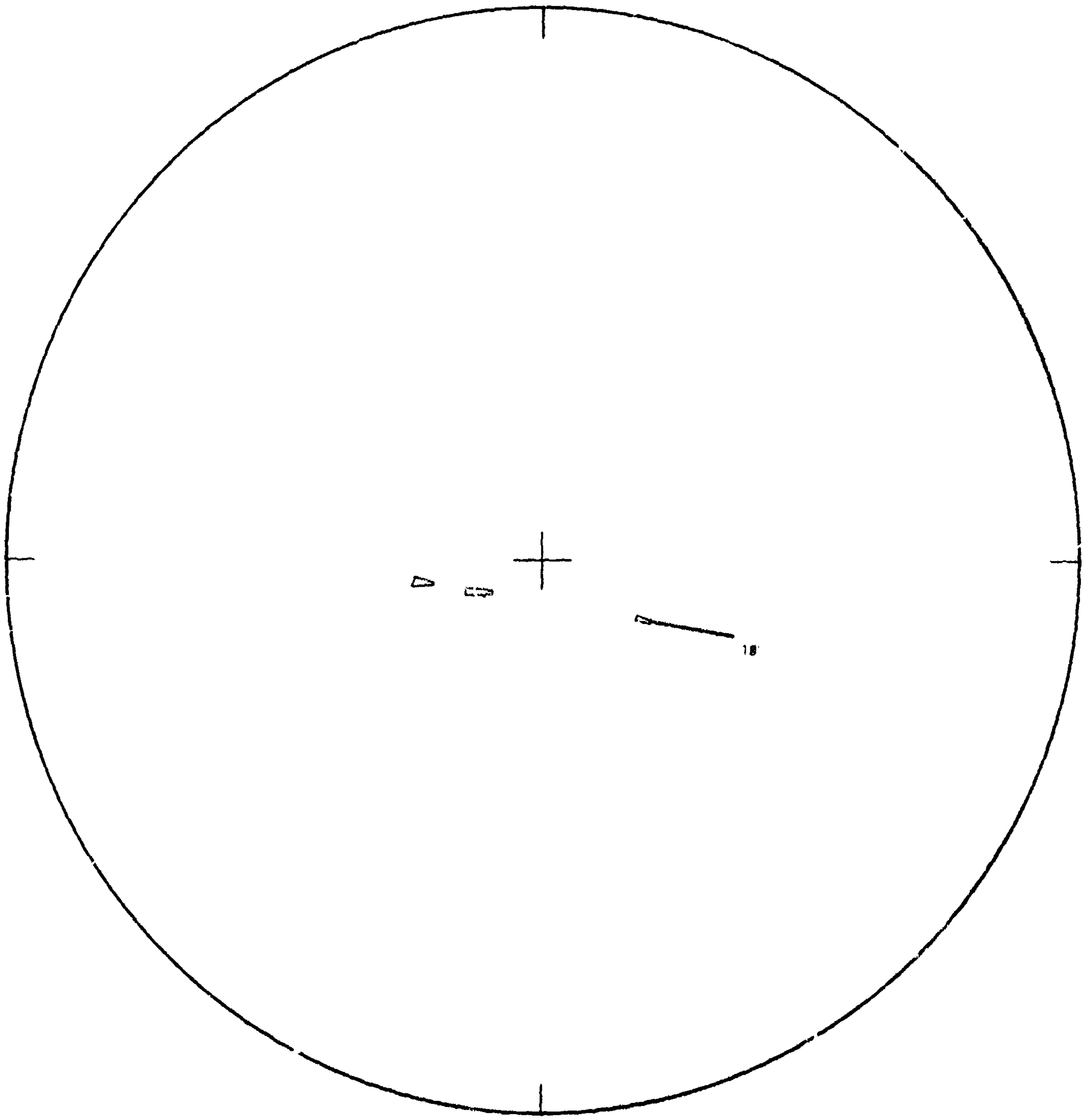
Earthside

Apollo 8	
Apollo 10	
Apollo 12	
Apollo 14	

APOLLO MISSION
80 mm F.L.
Stereographic
B & W PHOTOGRAPHY

PHOTO INDEX NO. I (17)

Dec. 1971



Earthside

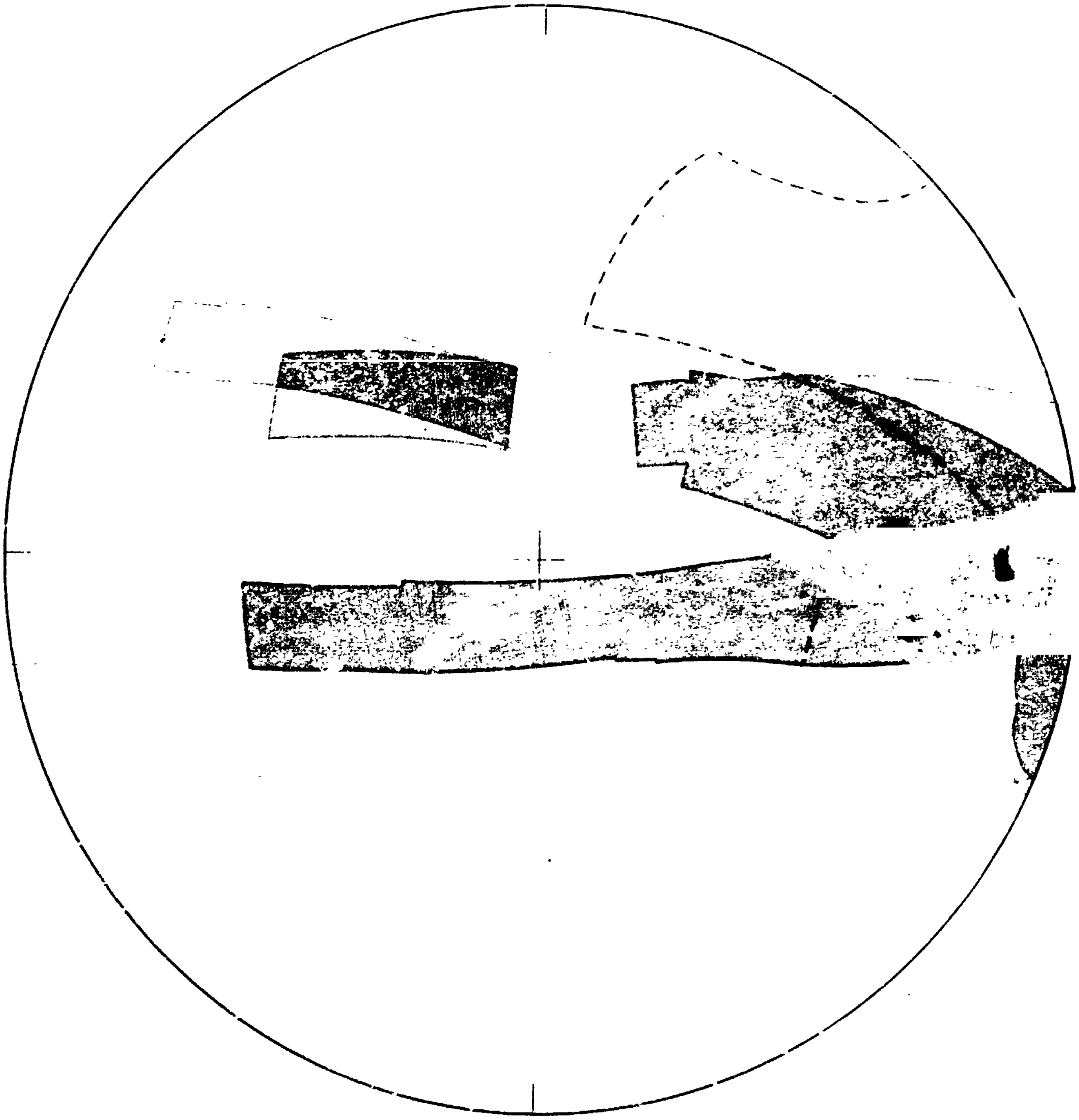
APOLLO MISSION
500 mm F.L. (18" where noted)
Stereographic
B & W PHOTOGRAPHY

Apollo 12
Apollo 14

PHOTO INDEX NO. I (18)

Dec. 1971

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR



Earthside

Apollo 15
Apollo 16 transearth
Apollo 17

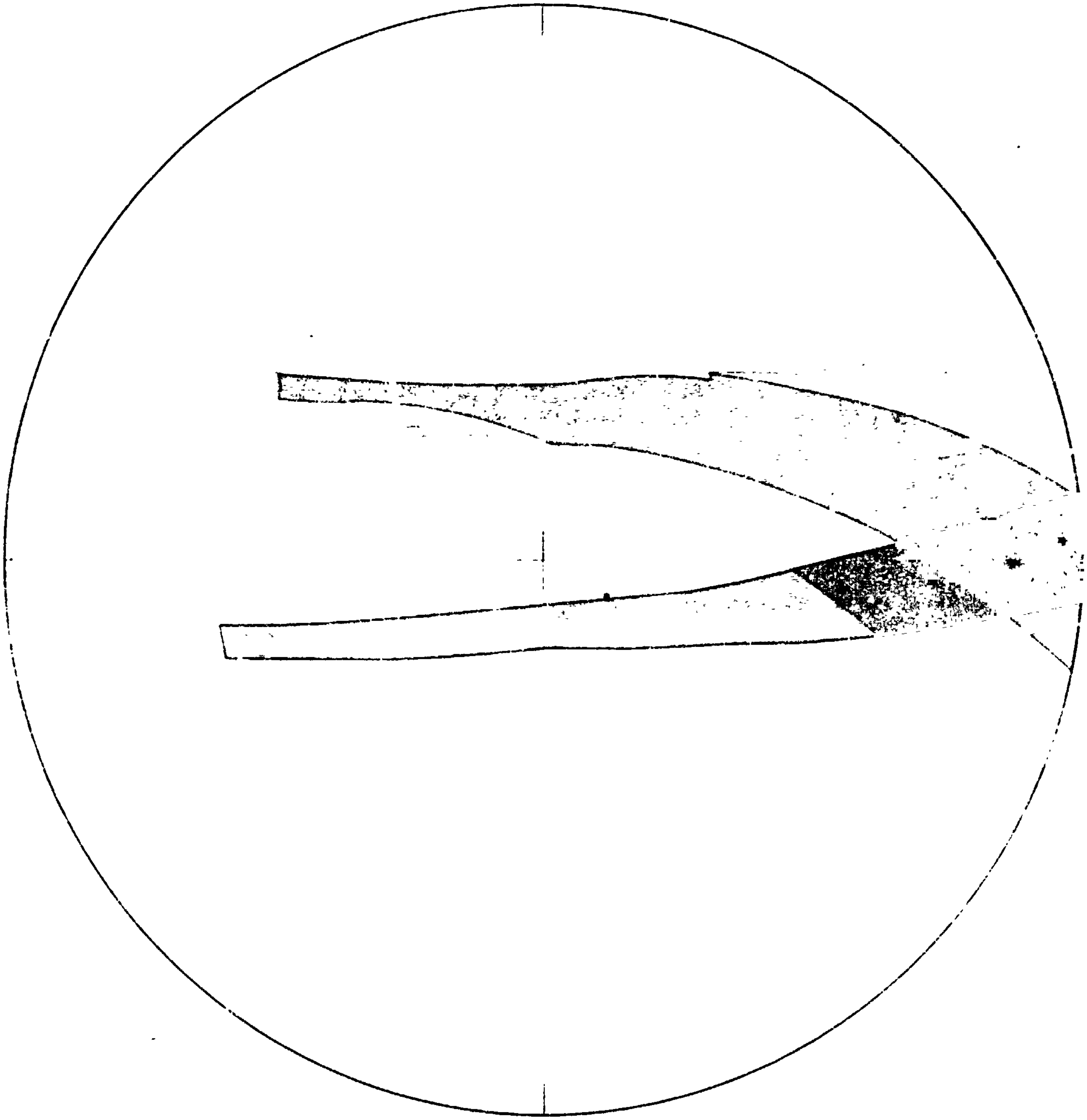
APOLLO MISSION
24" Panoramic

B&W PHOTOGRAPHY

PHOTO INDEX NO. I (19)

July 1974

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR



Earthside

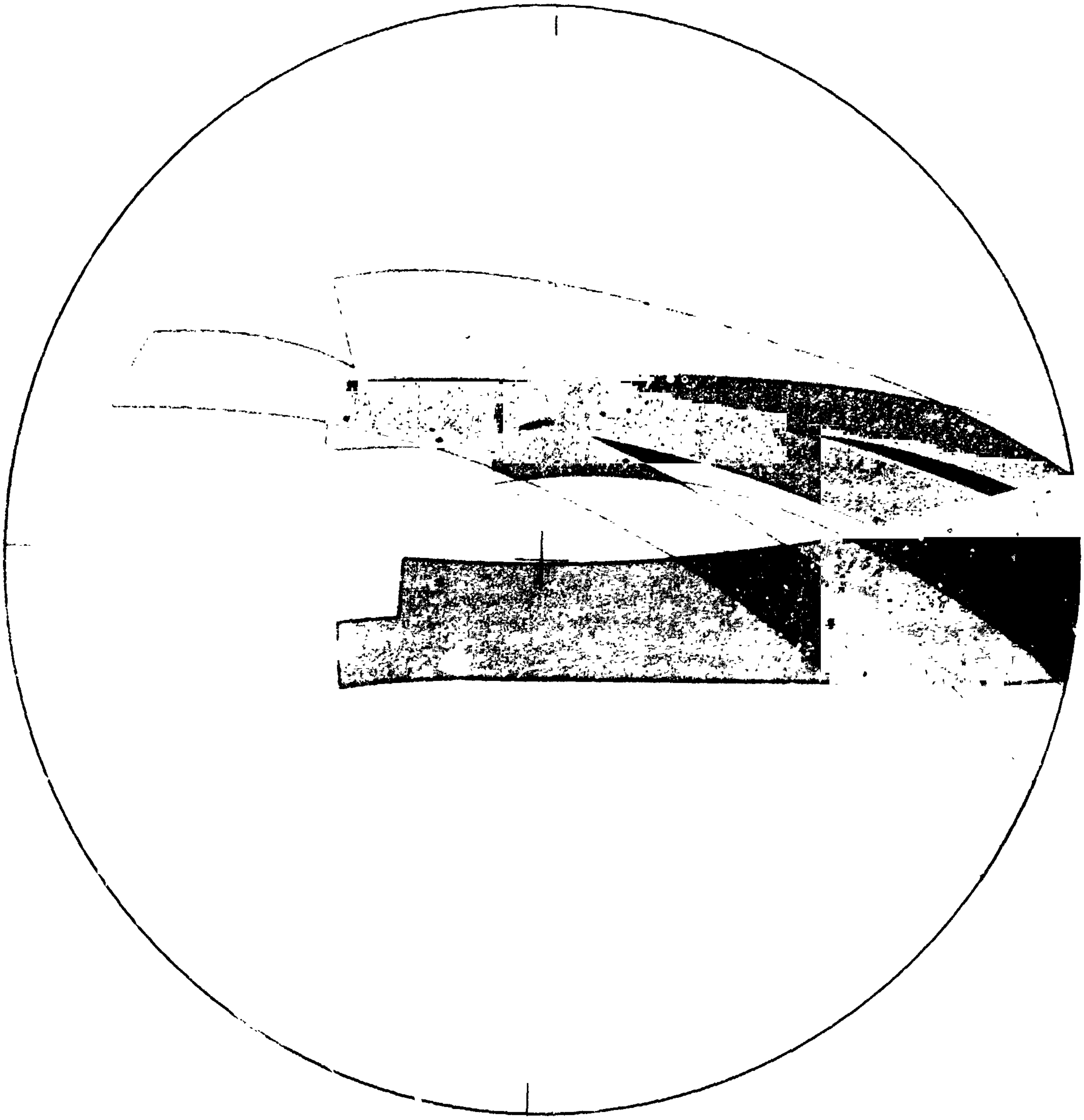
APOLLO MISSION
3" Mapping
Near Vertical
B&W PHOTOGRAPHY

PHOTO INDEX NO. I (20)

July 1974

Apollo 15
Apollo 16
Apollo 17

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR



Earthside

Apollo 15

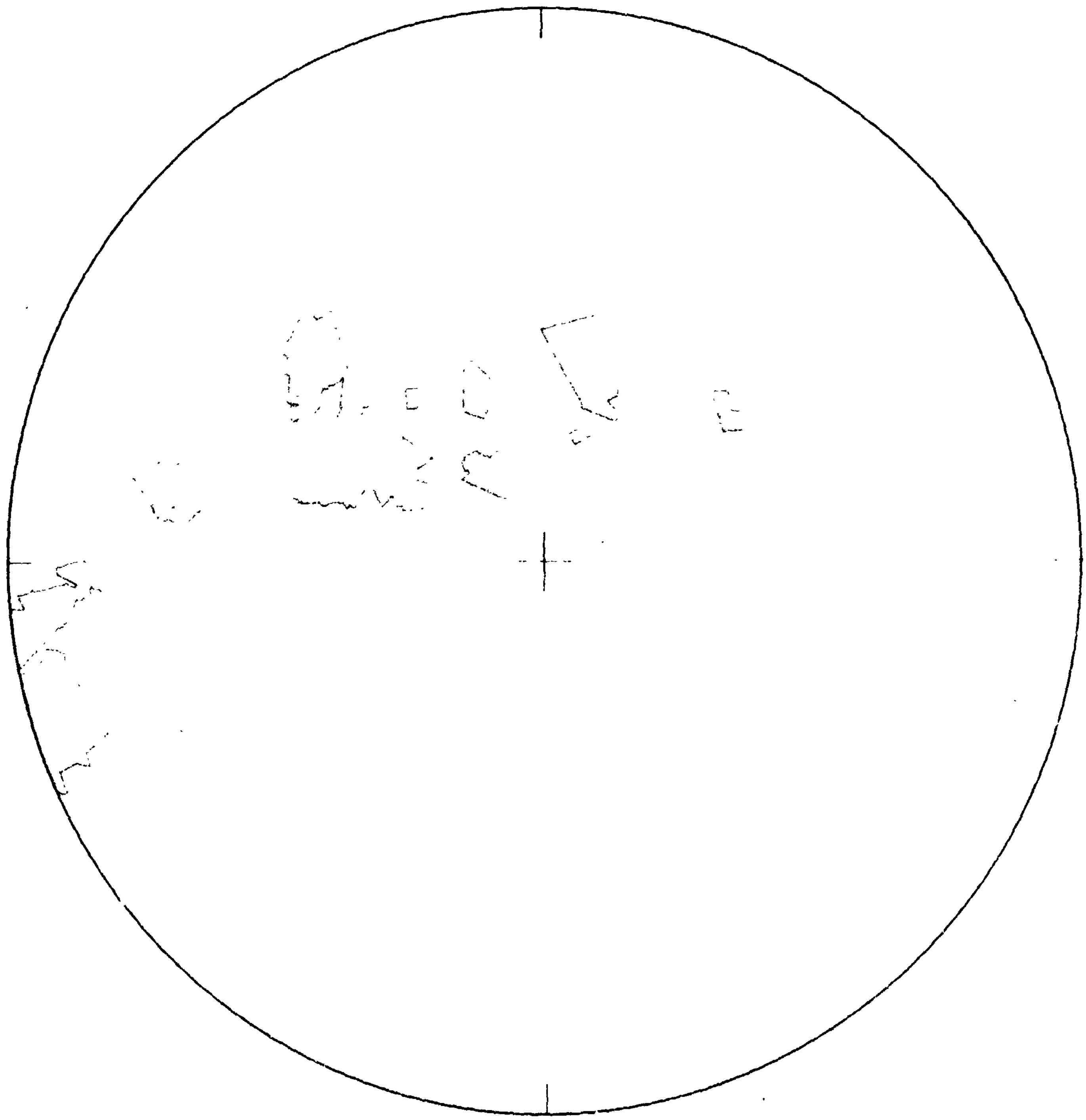
Apollo 16

Apollo 17

APOLLO MISSION
3" Mapping
Oblique
B&W PHOTOGRAPHY

PHOTO INDEX NO. I (21)

July 1974



Earthside

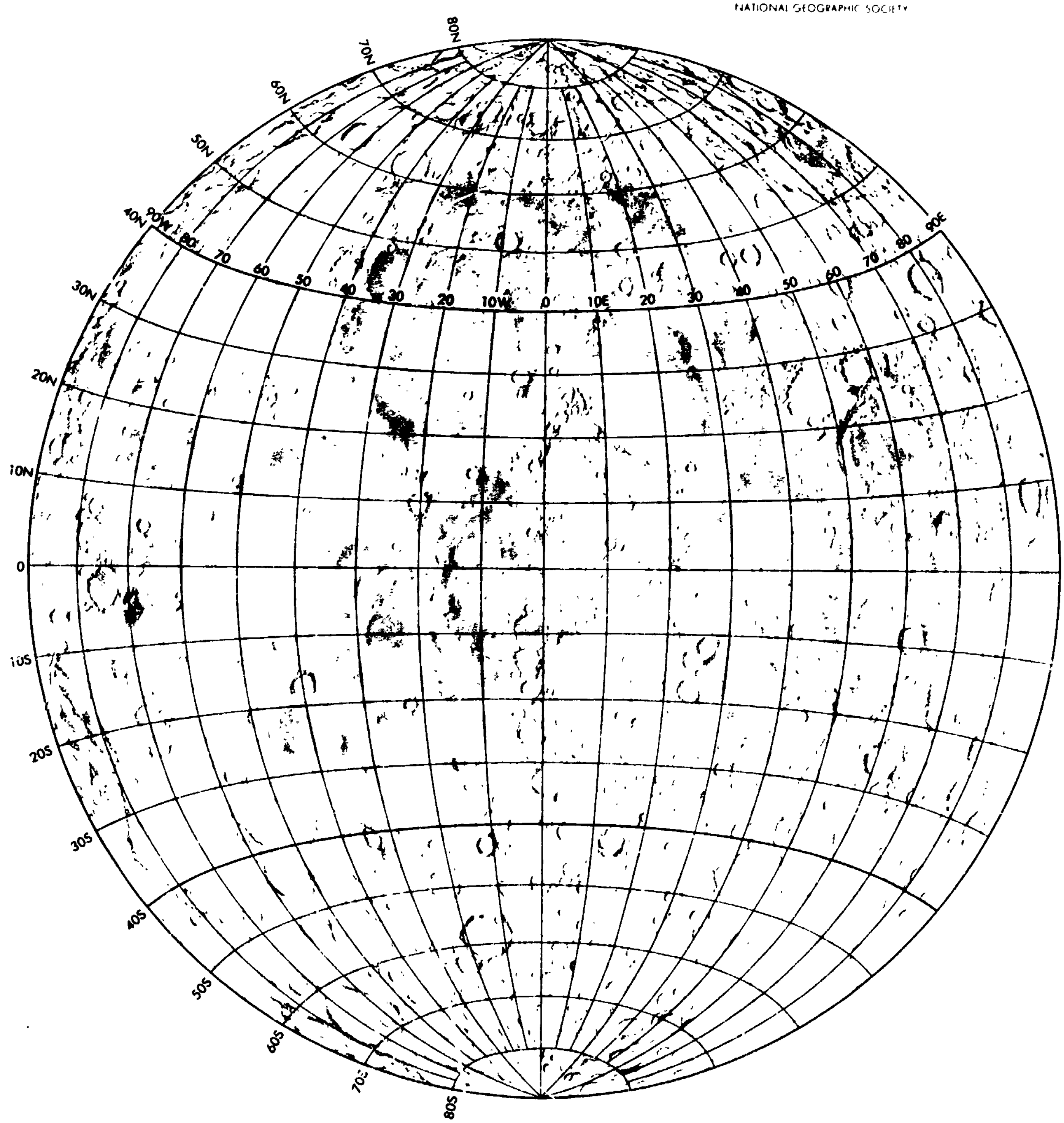
APOLLO MISSION
55mm F.L.
Oblique
B &W PHOTOGRAPHY

Apollo 17

PHOTO INDEX NO. I (22)

July 1974

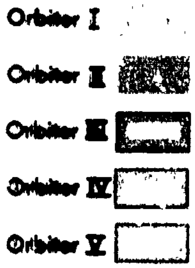
BASE MAP COURTESY OF NATIONAL GEOGRAPHIC SOCIETY



Earthside

PHOTO INDEX BASE MAP NO I

Farside



LUNAR ORBITER MISSION
80 mm F.L.
Near Vertical
B&W PHOTOGRAPHY

PHOTO INDEX NO. II (1)

Dec. 1971

Farside

LUNAR ORBITER MISSION
80 mm F.L.
Oblique
B&W PHOTOGRAPHY

Orbiter I
Orbiter II
Orbiter V

PHOTO INDEX NO. II (2)
Dec 1971

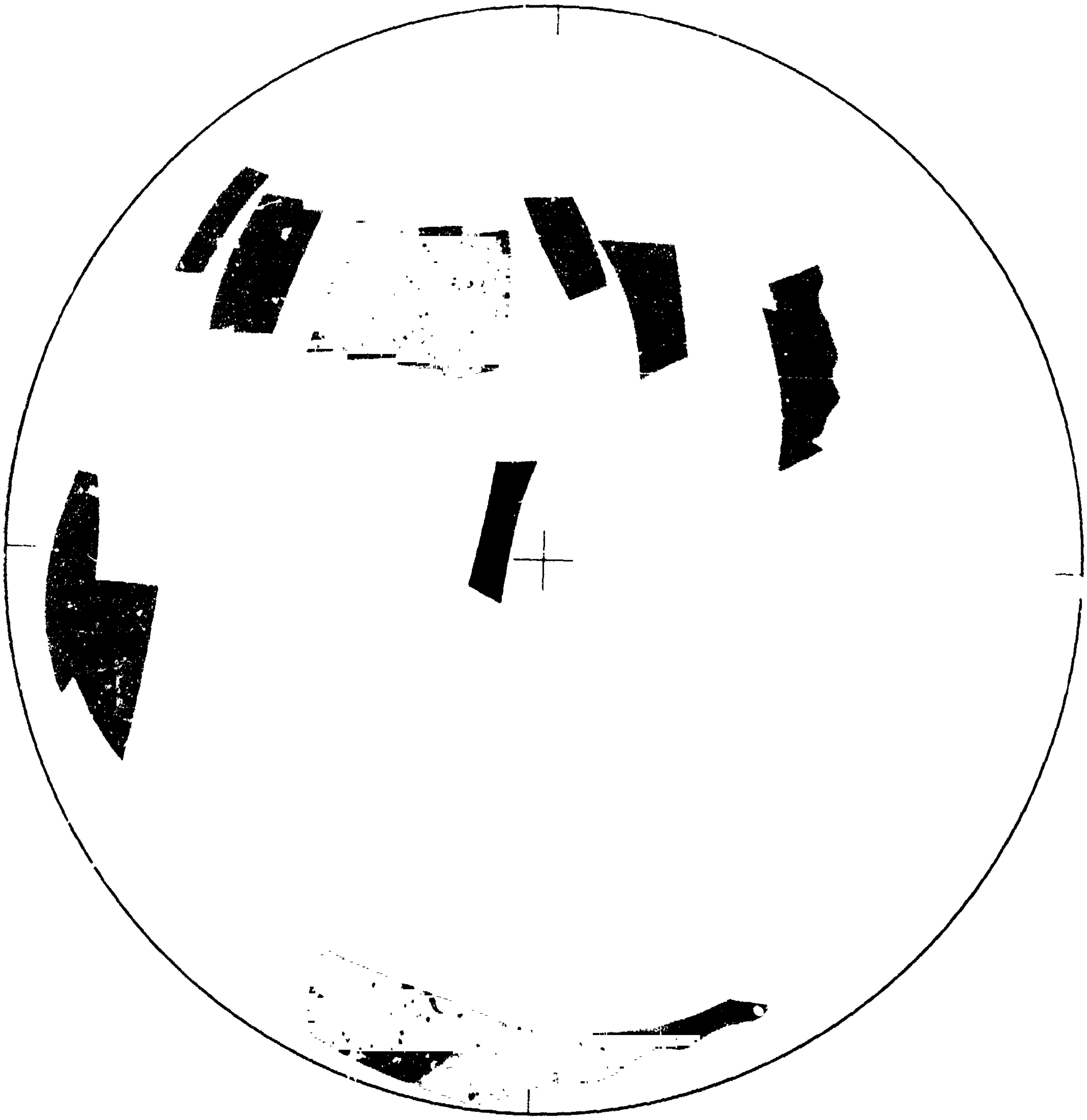
Farside

Orbiter I
Orbiter II
Orbiter III
Orbiter IV
Orbiter V

LUNAR ORBITER MISSION
610 mm F.L.
Near Vertical
B&W PHOTOGRAPHY

PHOTO INDEX NO. II (3)

Dec. 1971



Farside

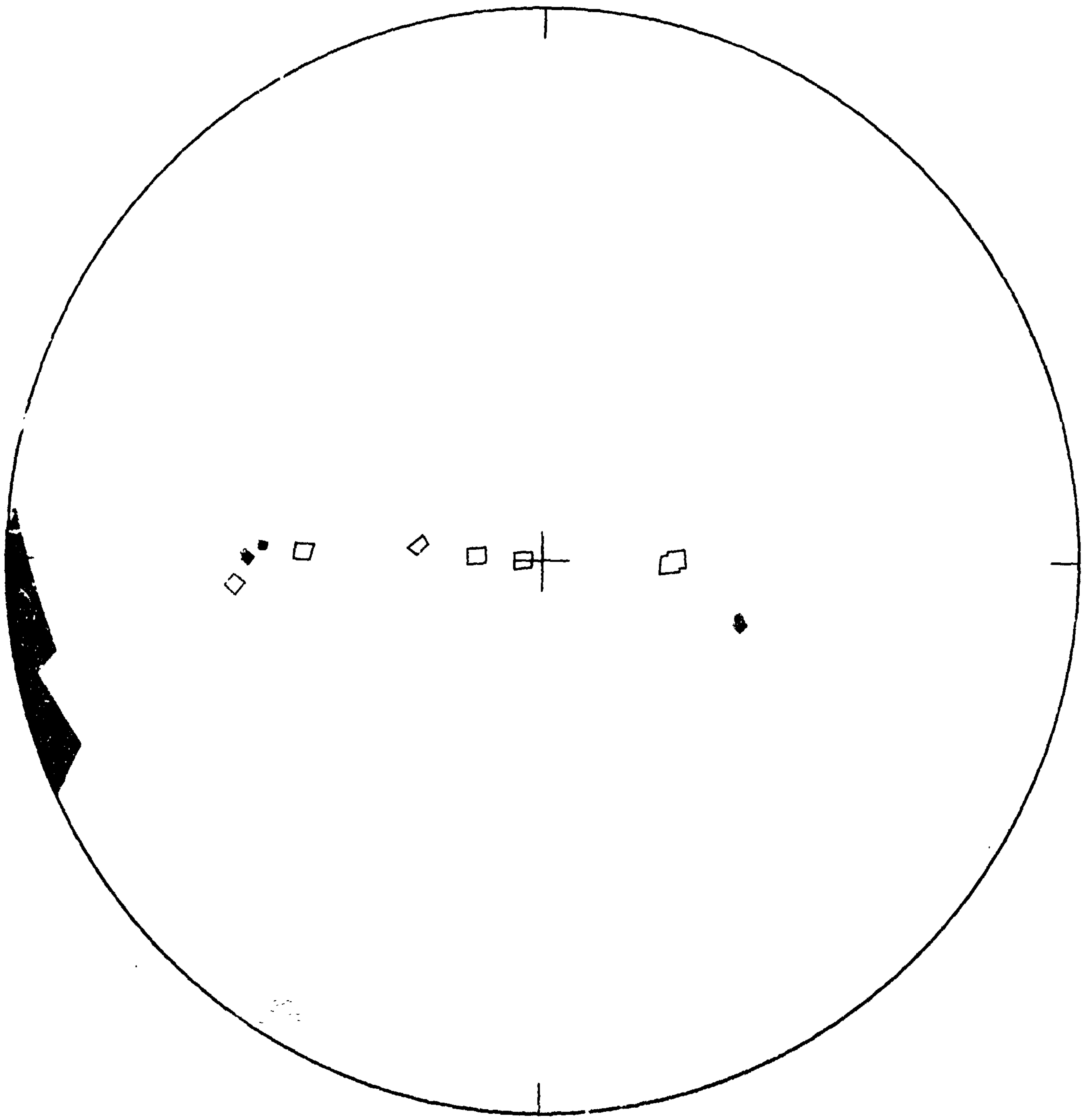
Orbiter I

Orbiter II

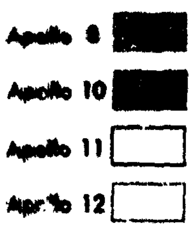
Orbiter V

LUNAR ORBITER MISSION
610 mm F.L.
Oblique
B&W PHOTOGRAPHY

PHOTO INDEX NO. II (4)
Dec. 1971



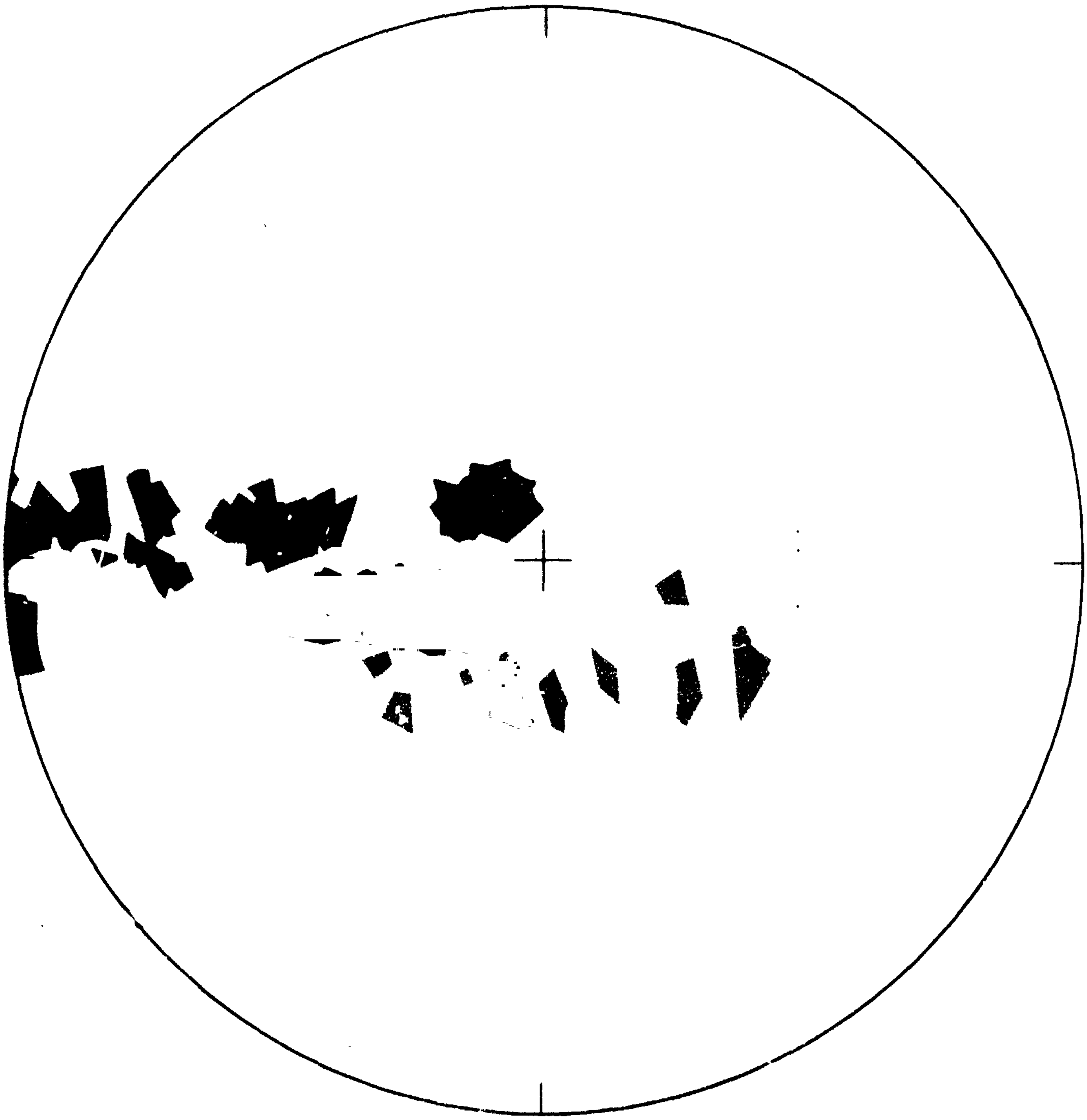
Farside



APOLLO MISSION
80 mm F.L.
Near Vertical
B & W PHOTOGRAPHY

PHOTO INDEX NO. II (S)
Dec. 1971

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR



Farside

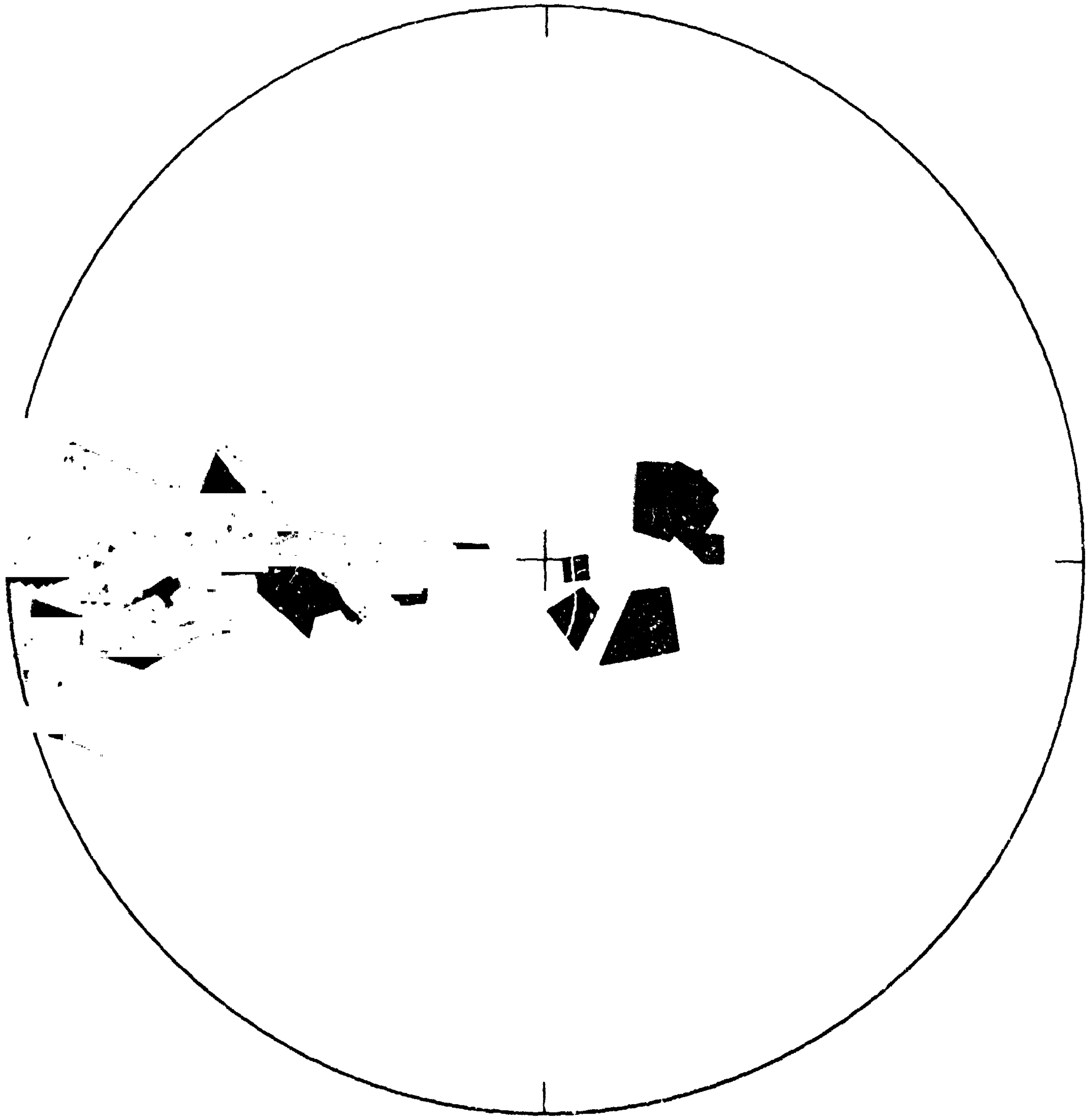
APOLLO MISSION
80 mm F.L.
Oblique
B & W PHOTOGRAPHY

Apollo 8

Apollo 10

PHOTO INDEX NO. X (4)

Dec. 1971



Farside

Apollo 11

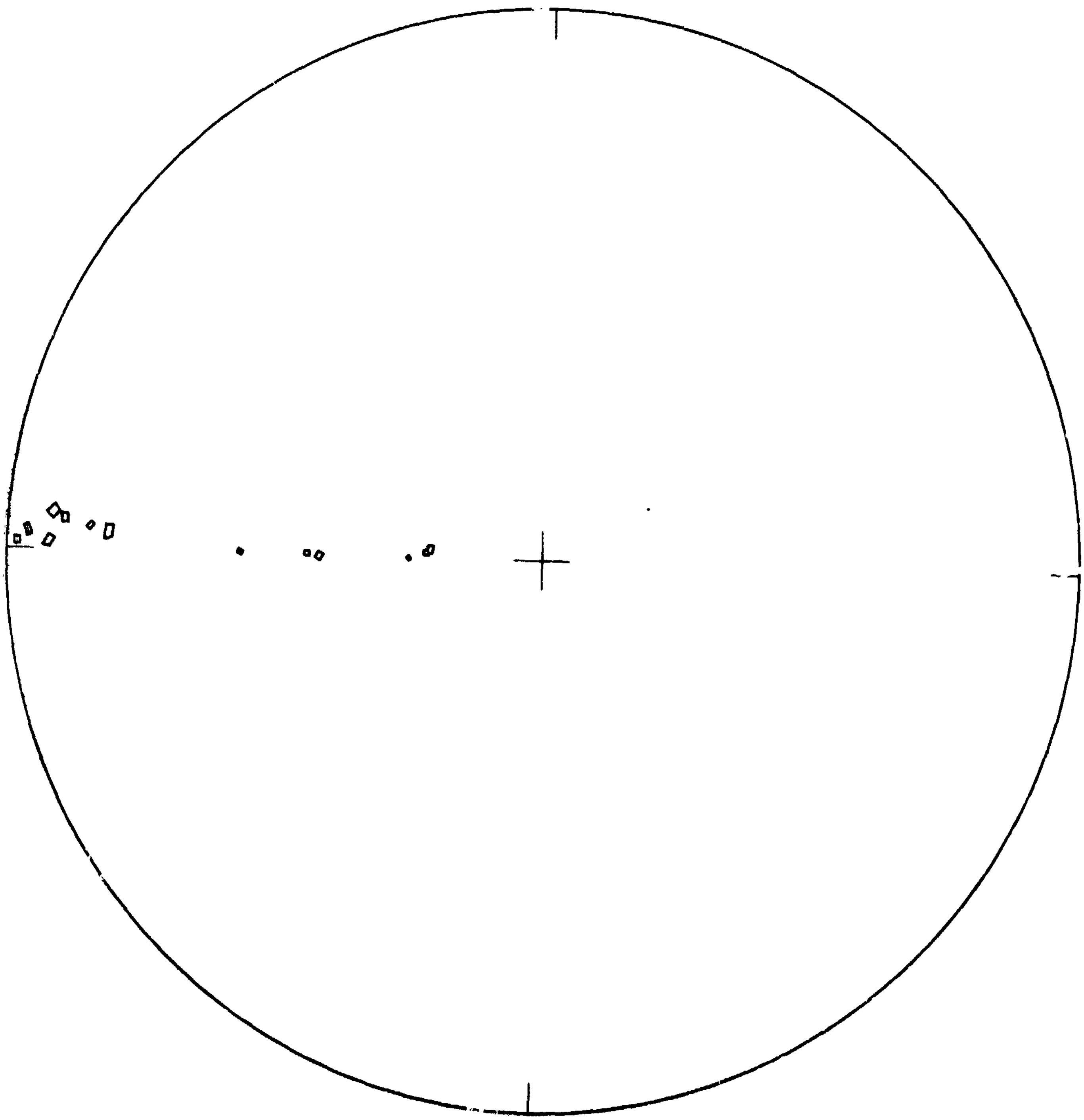
Apollo 14

APOLLO MISSION
80 mm F.L.
Oblique
B & W PHOTOGRAPHY

PHOTO INDEX NO. V (7)

Dec. 1971

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR



Farside

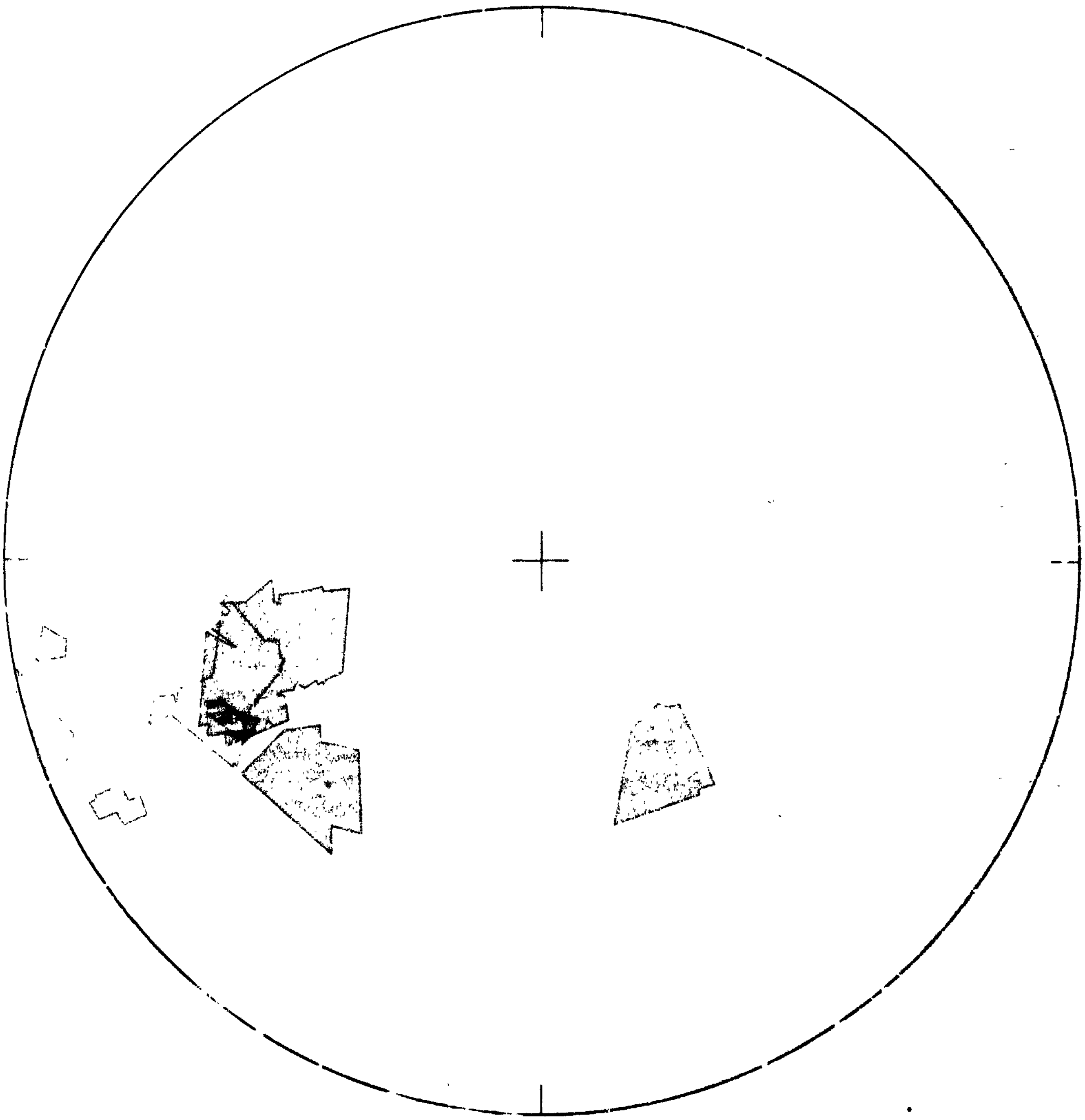
Apollo 10 (filled)

Apollo 11 (open)

APOLLO MISSION
250 mm F.L.
Near Vertical
B & W PHOTOGRAPHY

PHOTO INDEX NO. [illegible]

Dec 1971



Farside

APOLLO MISSION
80mm F.L. (60mm where noted)
Oblique
B&W PHOTOGRAPHY

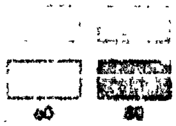
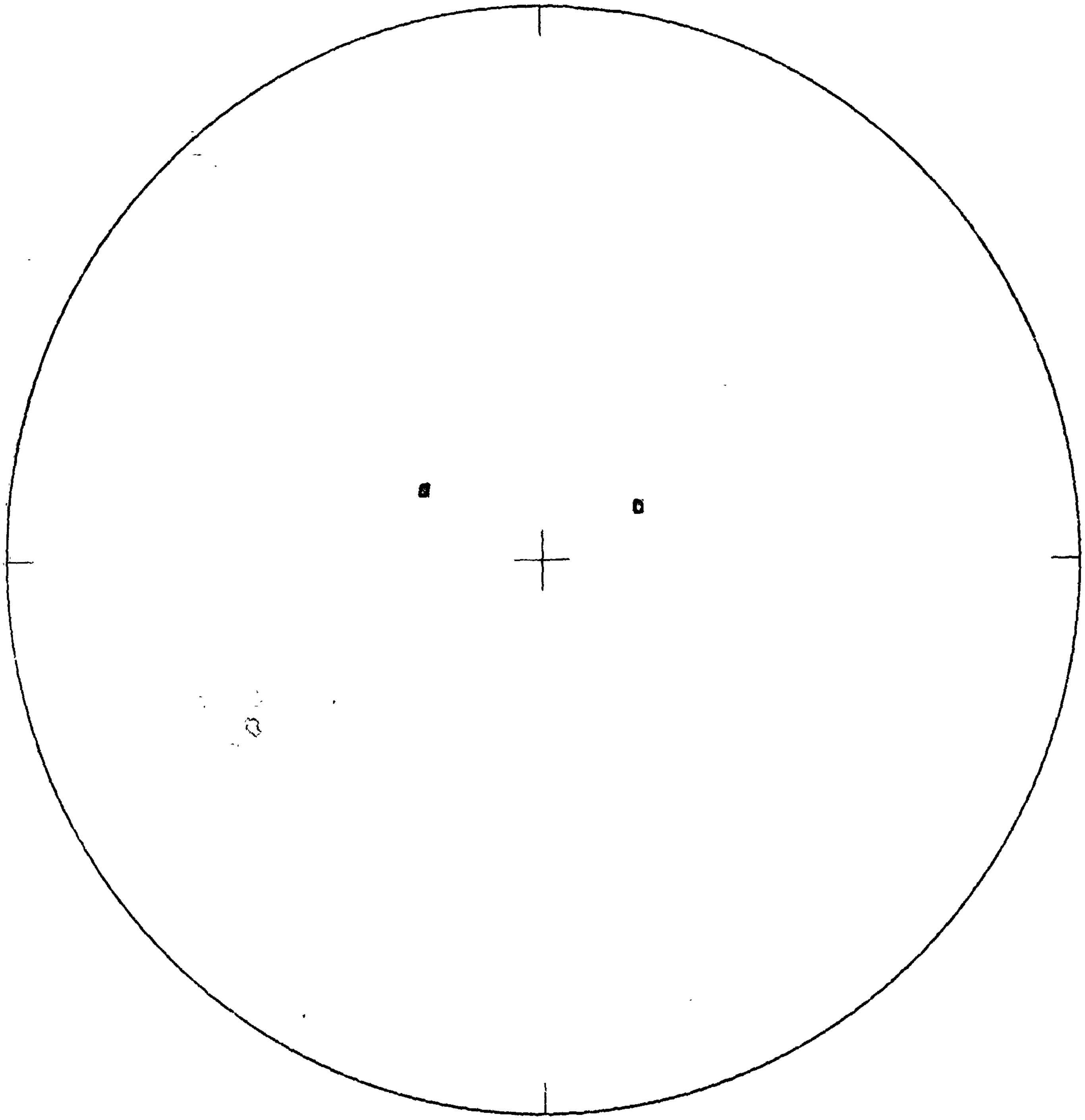


PHOTO INDEX NO. [illegible]

July [illegible]



Farside

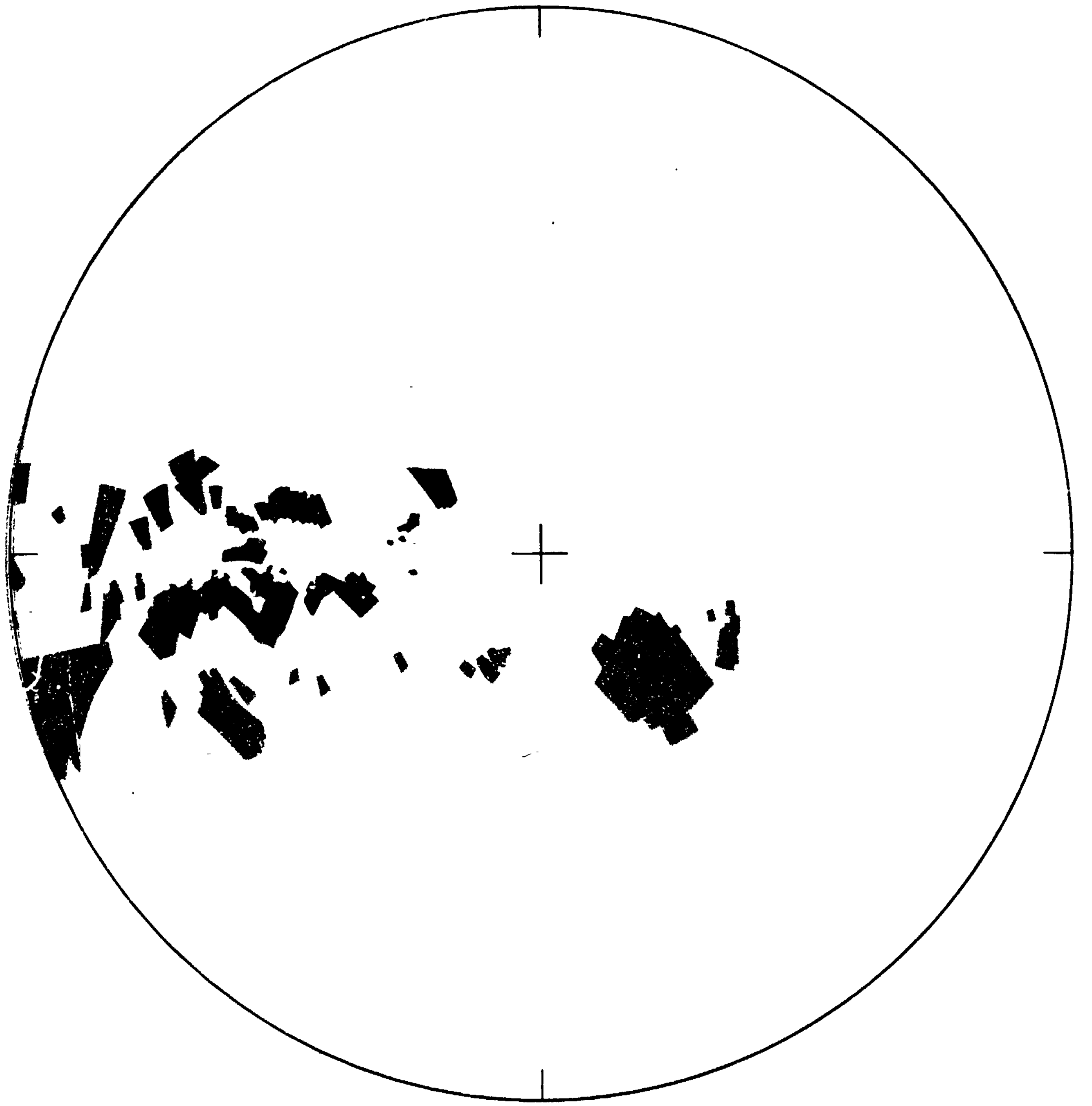
APOLLO MISSION
250mm F.L.
Near Vertical
B&W PHOTOGRAPHY

Apollo 15
Apollo 16
Apollo 17

PHOTO INDEX NO. II (8a)

July 1974

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

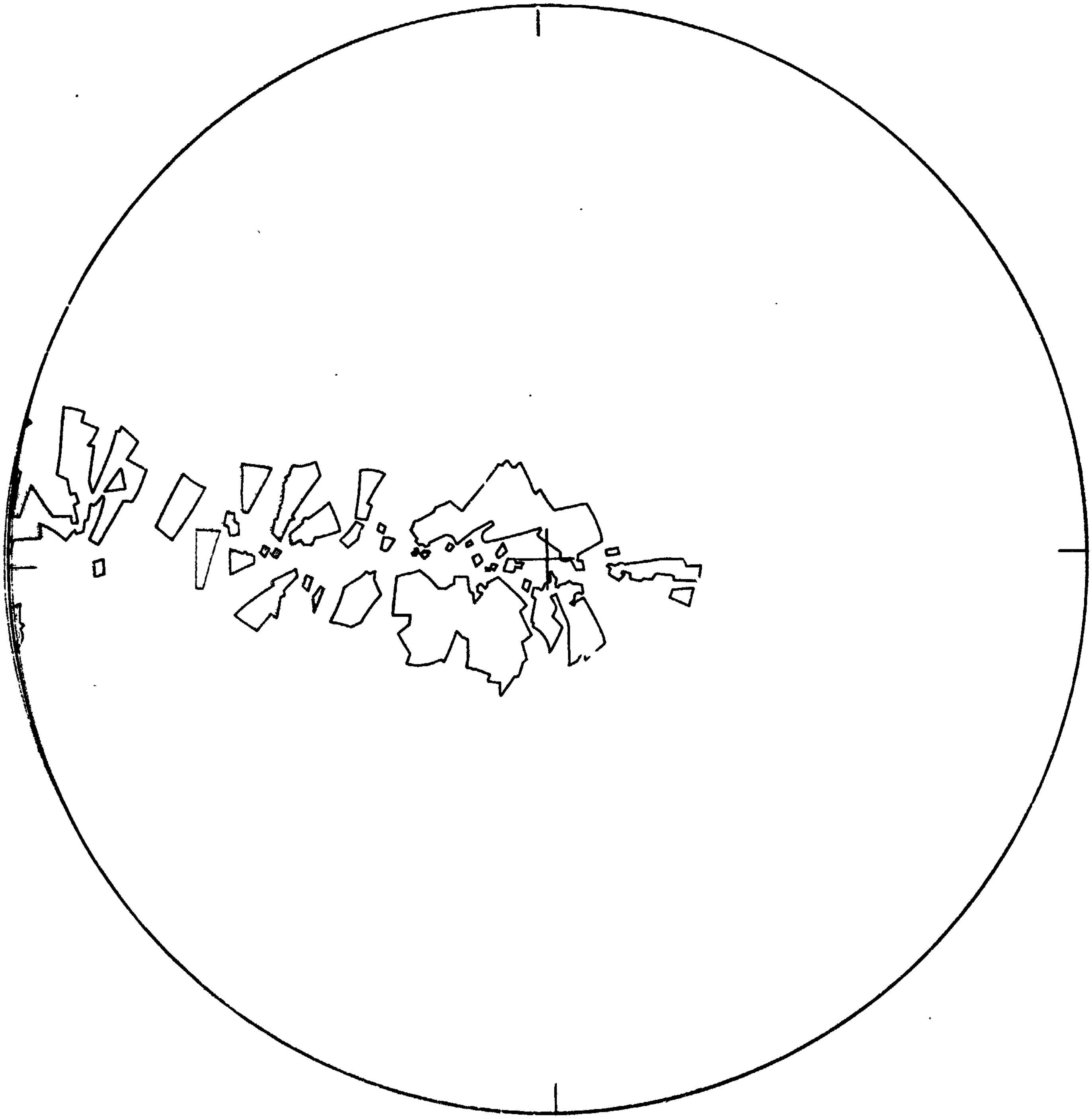


Farside

APOLLO MISSION
250 mm F.L.
Oblique
B & W PHOTOGRAPHY

Apollo 8
Apollo 10

PHOTO INDEX NO. II (9)
Dec. 1971

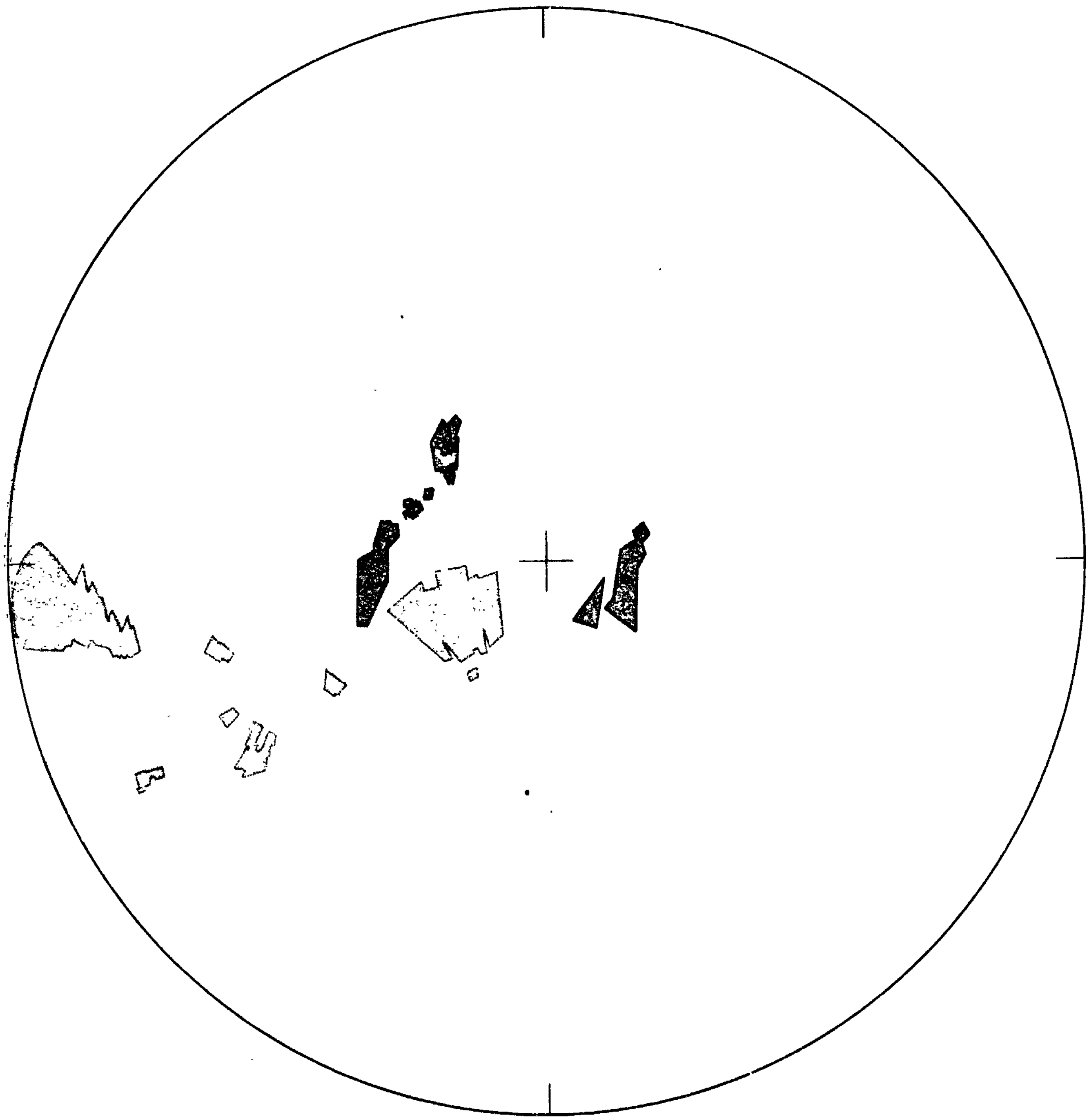


Farside

APOLLO MISSION
250 mm F.L.
Oblique
B & W PHOTOGRAPHY

Apollo 11
Apollo 12

PHOTO INDEX NO. II (10)
Dec. 1971



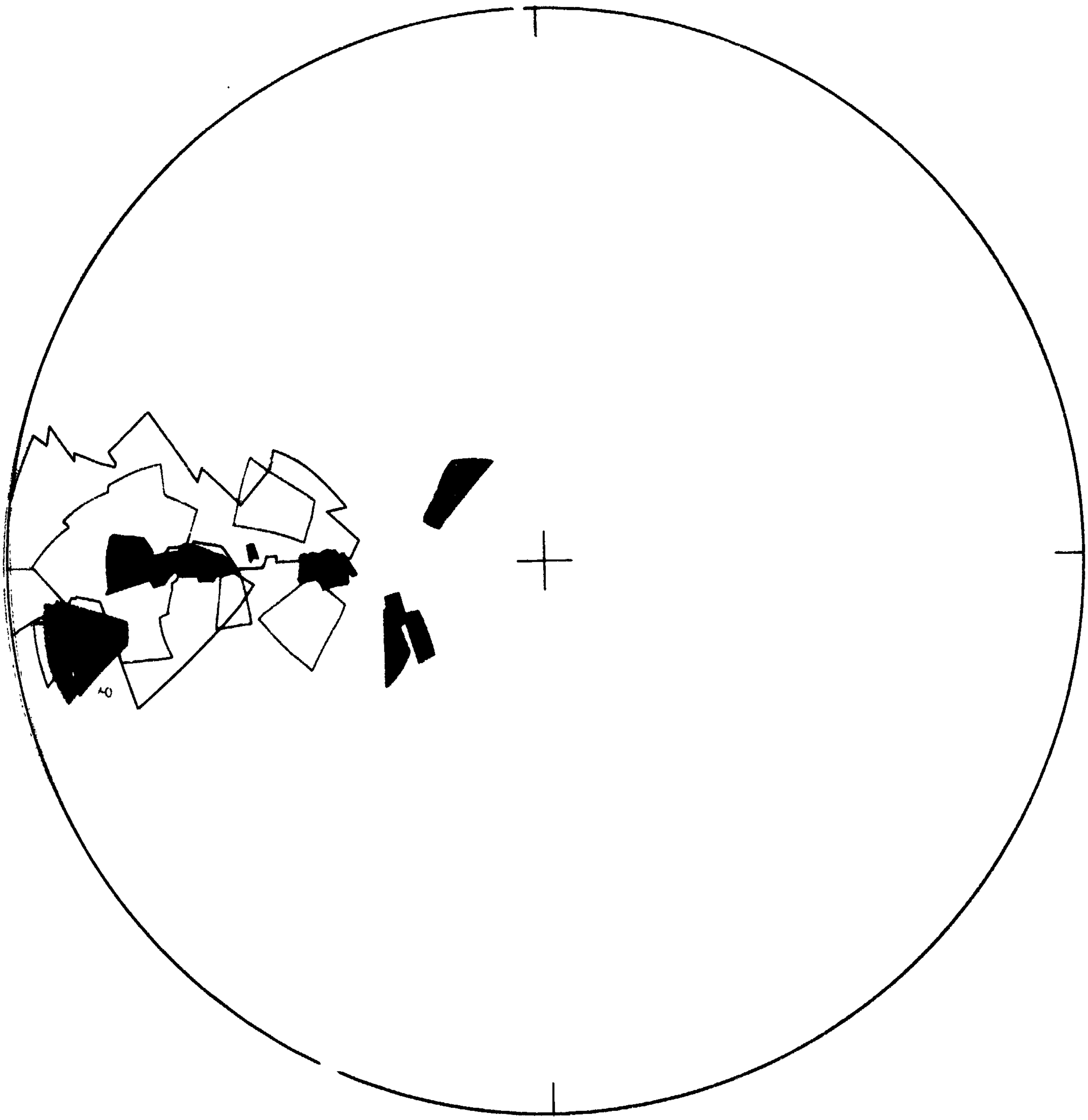
Farside

APOLLO MISSION
250mm F.L.
Oblique
B&W PHOTOGRAPHY

Apollo 15
Apollo 16
Apollo 17

PHOTO INDEX NO. II (10a)

July 1974



Farside

Apollo 10

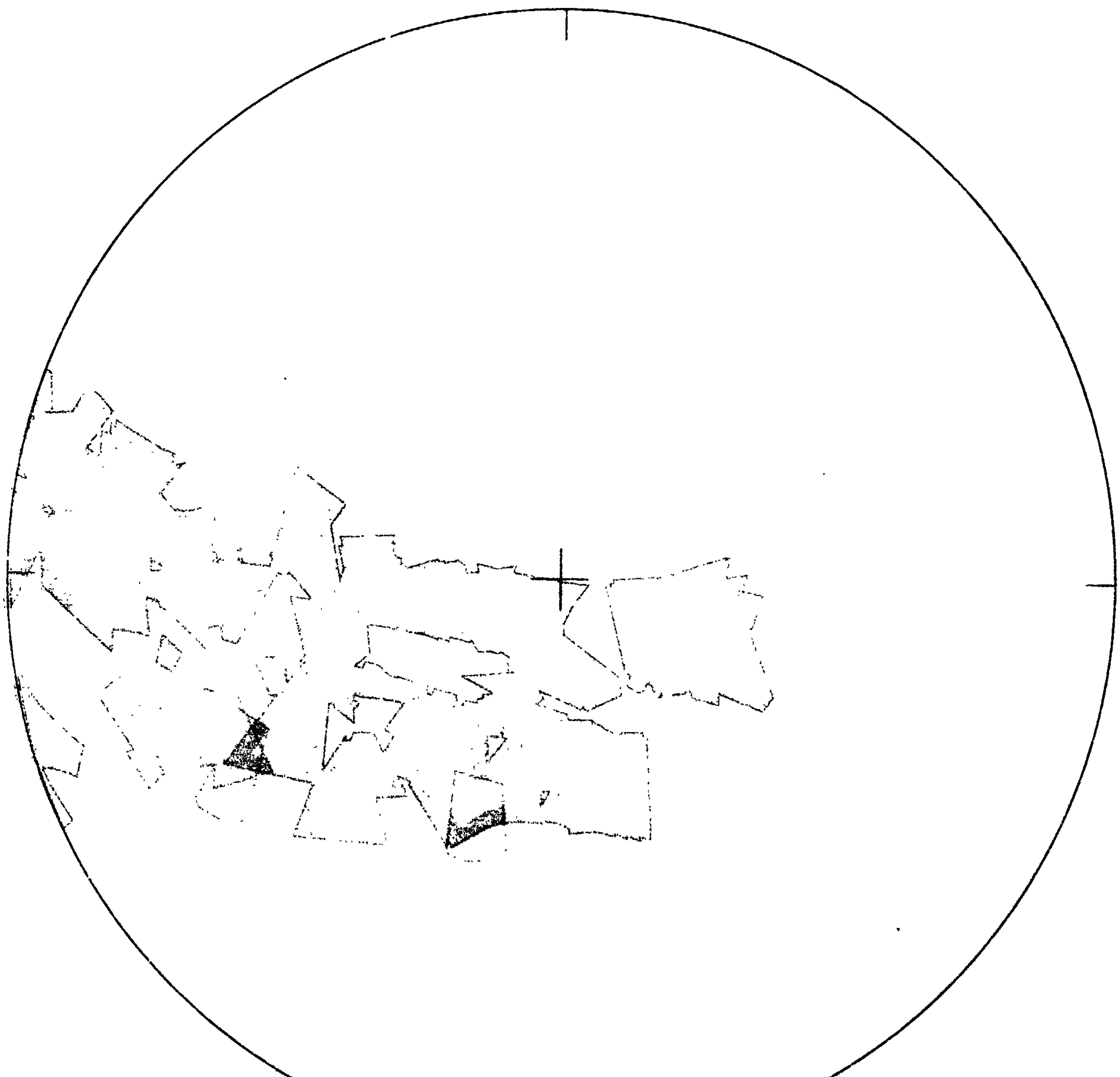
Apollo 11

Apollo 12

Apollo 14

APOLLO MISSION
80 mm F.L. (60 mm where noted)
Oblique
COLOR PHOTOGRAPHY

PHOTO INDEX NO. III(11)
Dec. 1971



Farside

APOLLO MISSION
60&80mm F.L.
Oblique
COLOR PHOTOGRAPHY

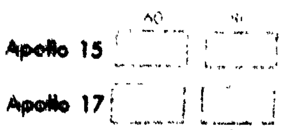
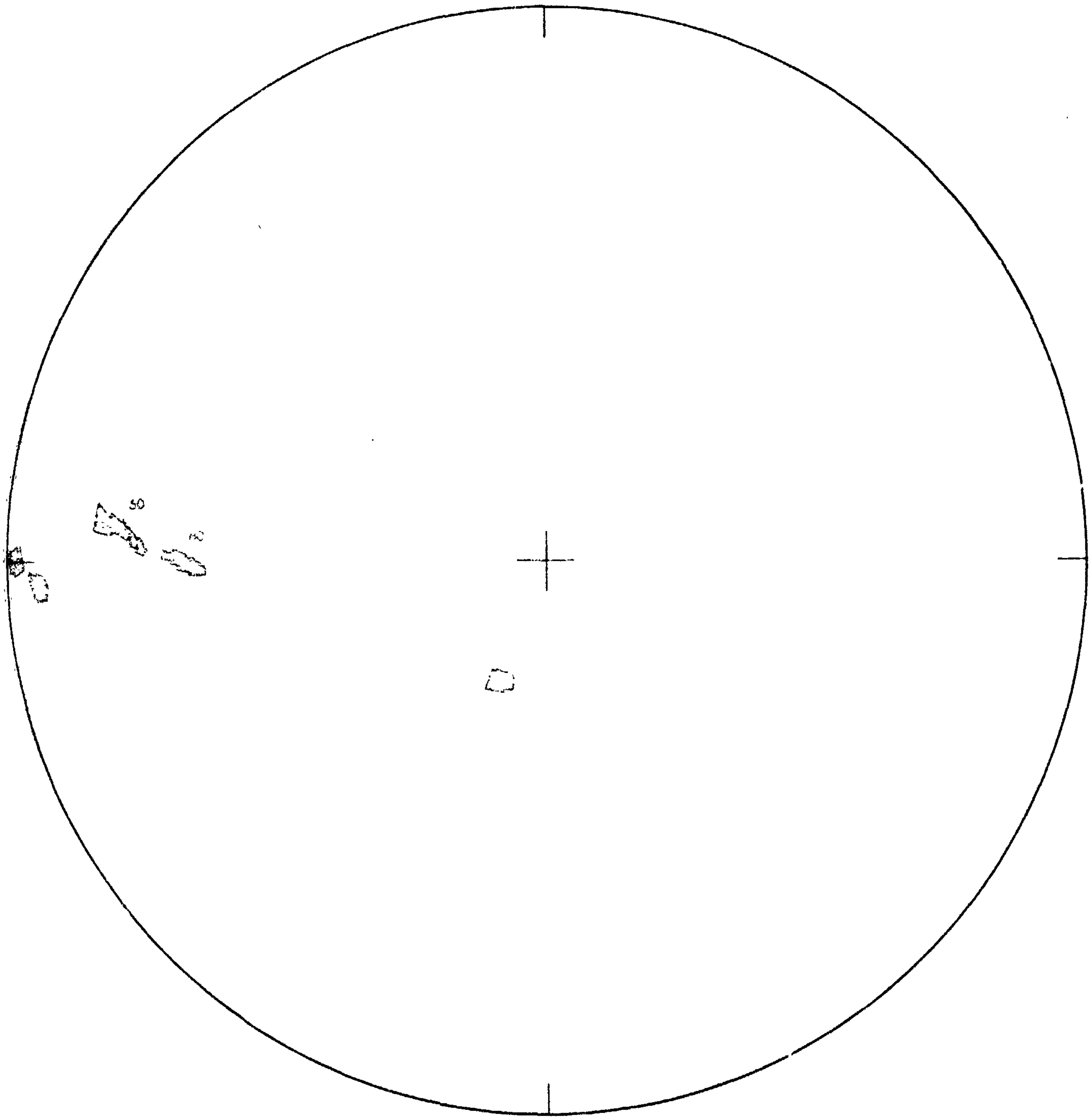


PHOTO INDEX NO. II (11a)
July 1974

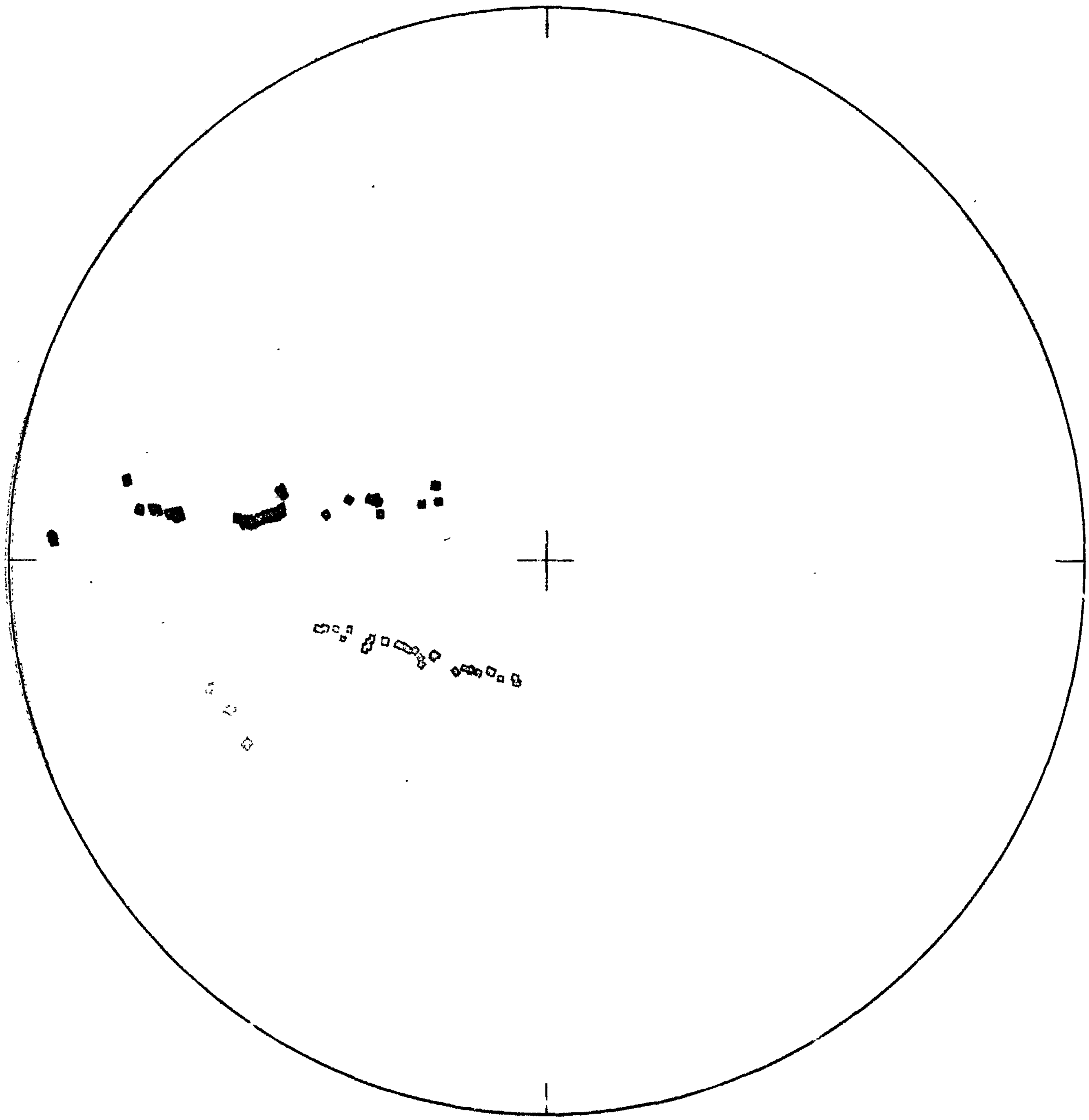


Farside

APOLLO MISSION
80mm F.L. (60mm where noted)
Near Vertical
COLOR PHOTOGRAPHY

Apollo 17

PHOTO INDEX NO. II (1b)
July 1974



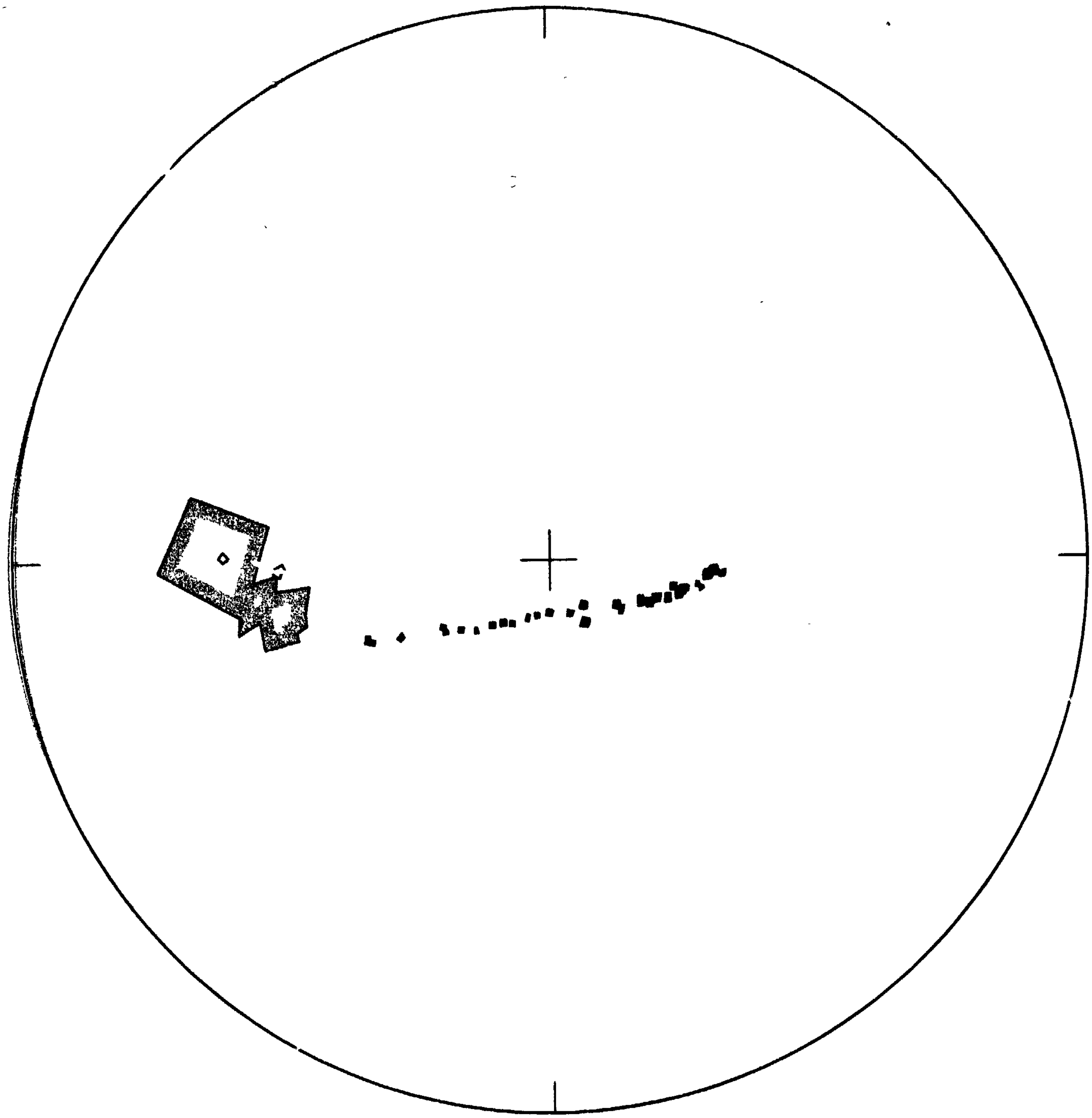
Farside

APOLLO MISSION
250mm F.L.
Near Vertical
COLOR PHOTOGRAPHY

Apollo 15
Apollo 16
Apollo 17

PHOTO INDEX NO. II (12a)

July 1974

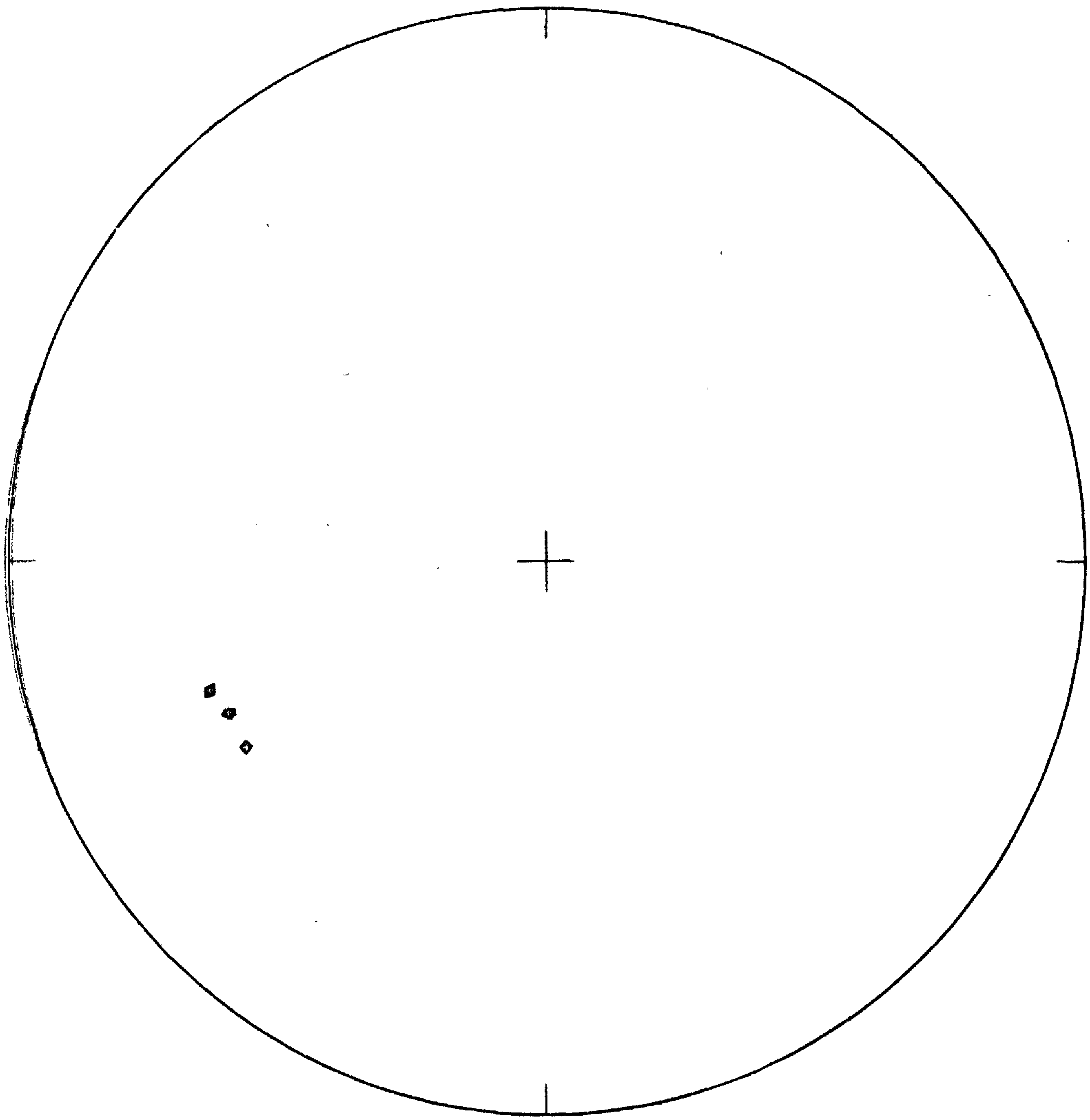


Farside

APOLLO MISSION
250 mm F.L.
Near Vertical
COLOR PHOTOGRAPHY

Apollo 8
Apollo 11
Apollo 13

PHOTO INDEX NO. II (12)
Dec. 1971

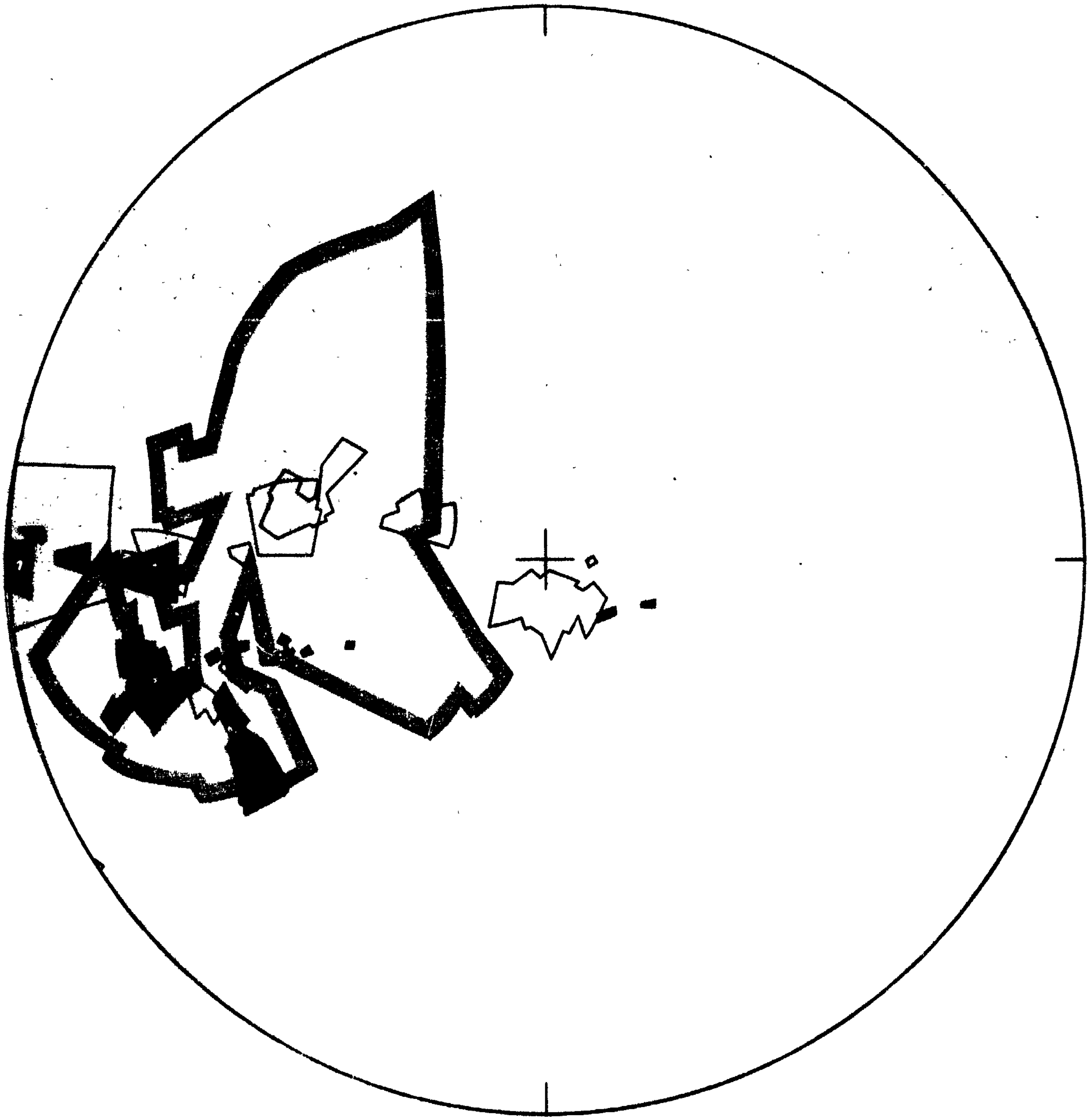


Farside

APOLLO MISSION
250mm F.L.
Near Vertical
COLOR PHOTOGRAPHY

Apollo 15

PHOTO INDEX NO. II (12a)
Aug. 1972



Apollo 8

Apollo 10

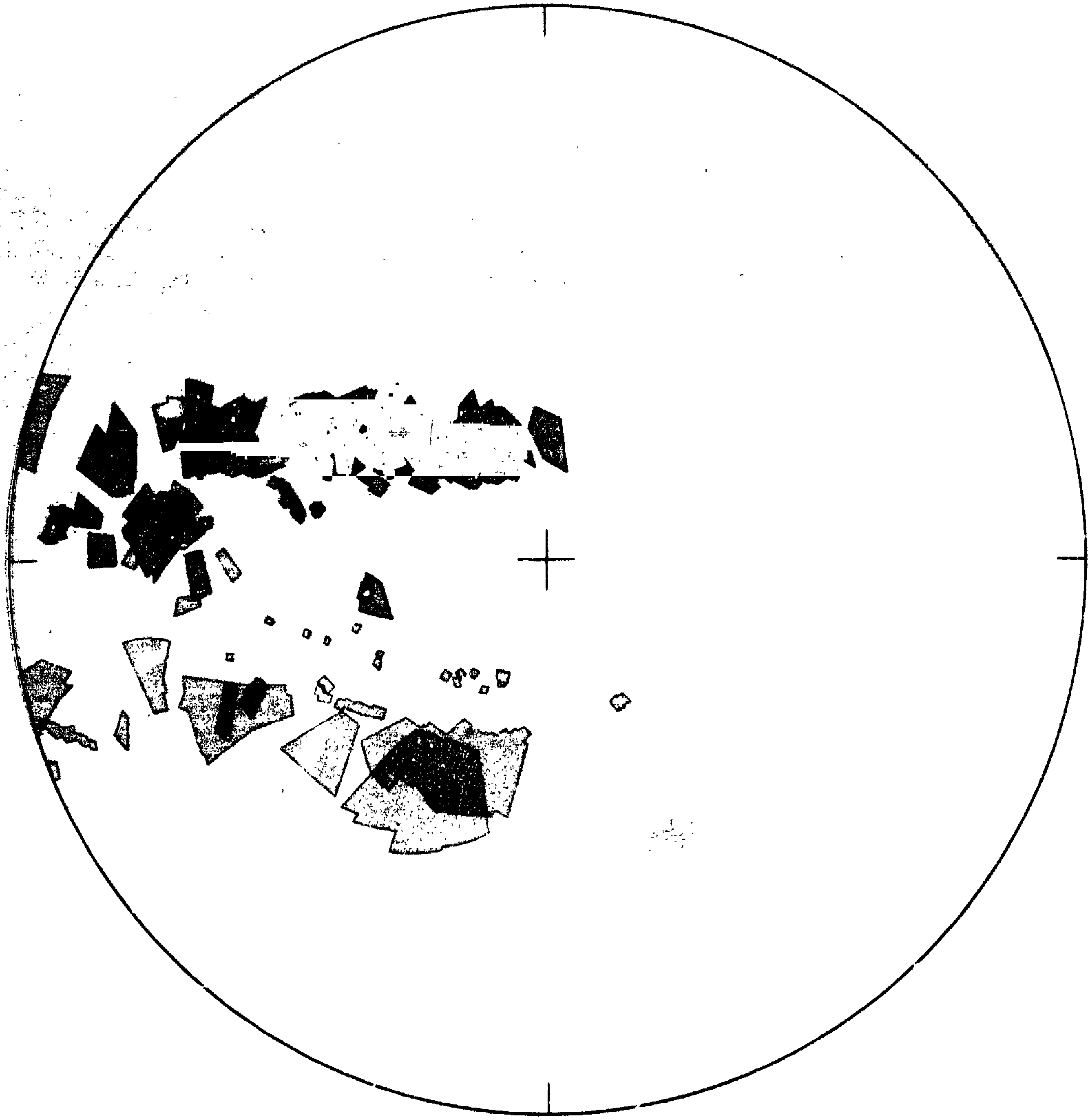
Apollo 11

Apollo 12

Apollo 13

APOLLO MISSION
250 mm F.L.
Oblique
COLOR PHOTOGRAPHY

PHOTO INDEX NO. II (13)
Dec. 1971



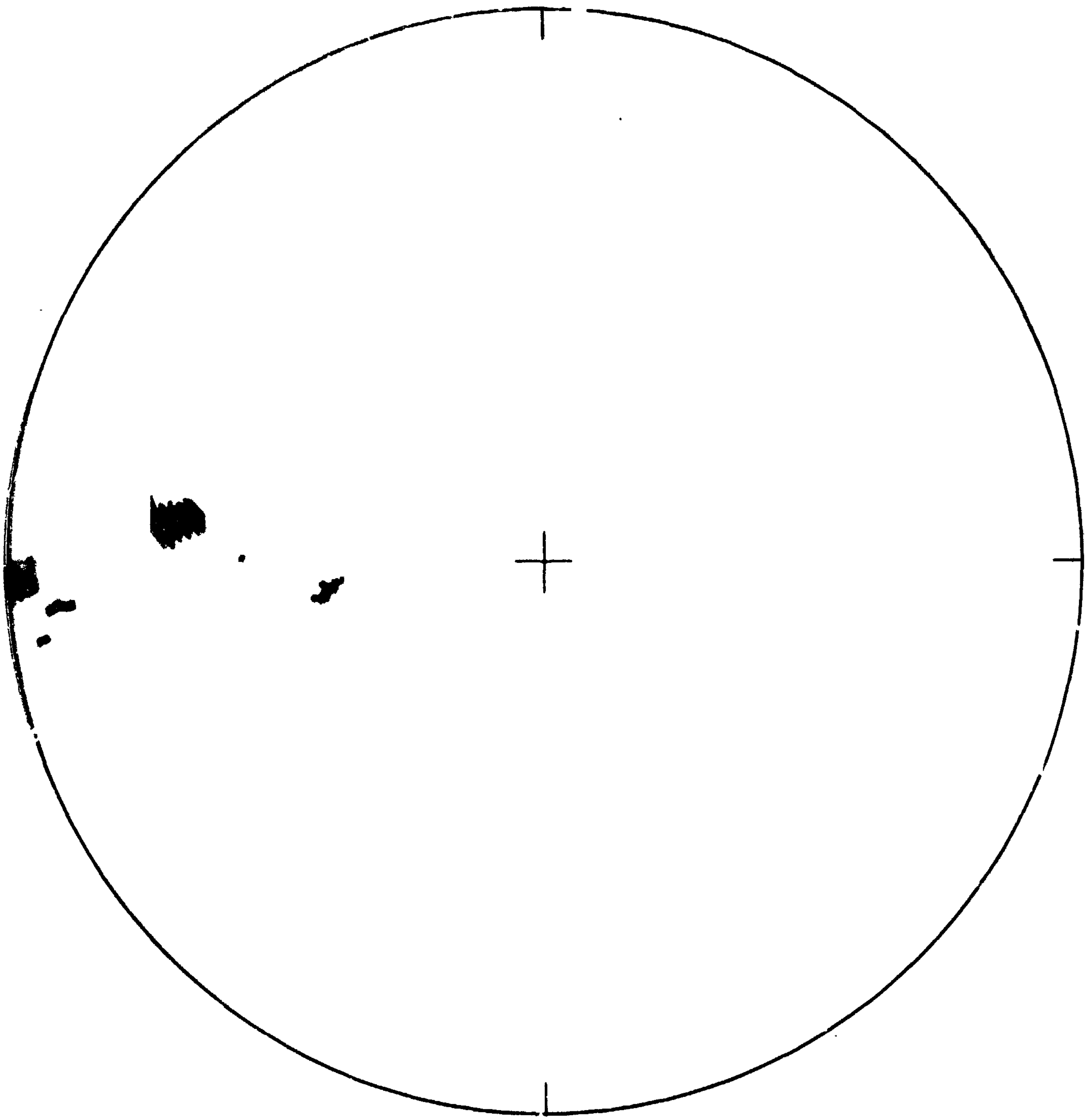
Farside

APOLLO MISSION
250mm F.L.
Oblique
COLOR PHOTOGRAPHY

Apollo 15
Apollo 16
Apollo 17

PHOTO INDEX NO. II (13a)

July 1974

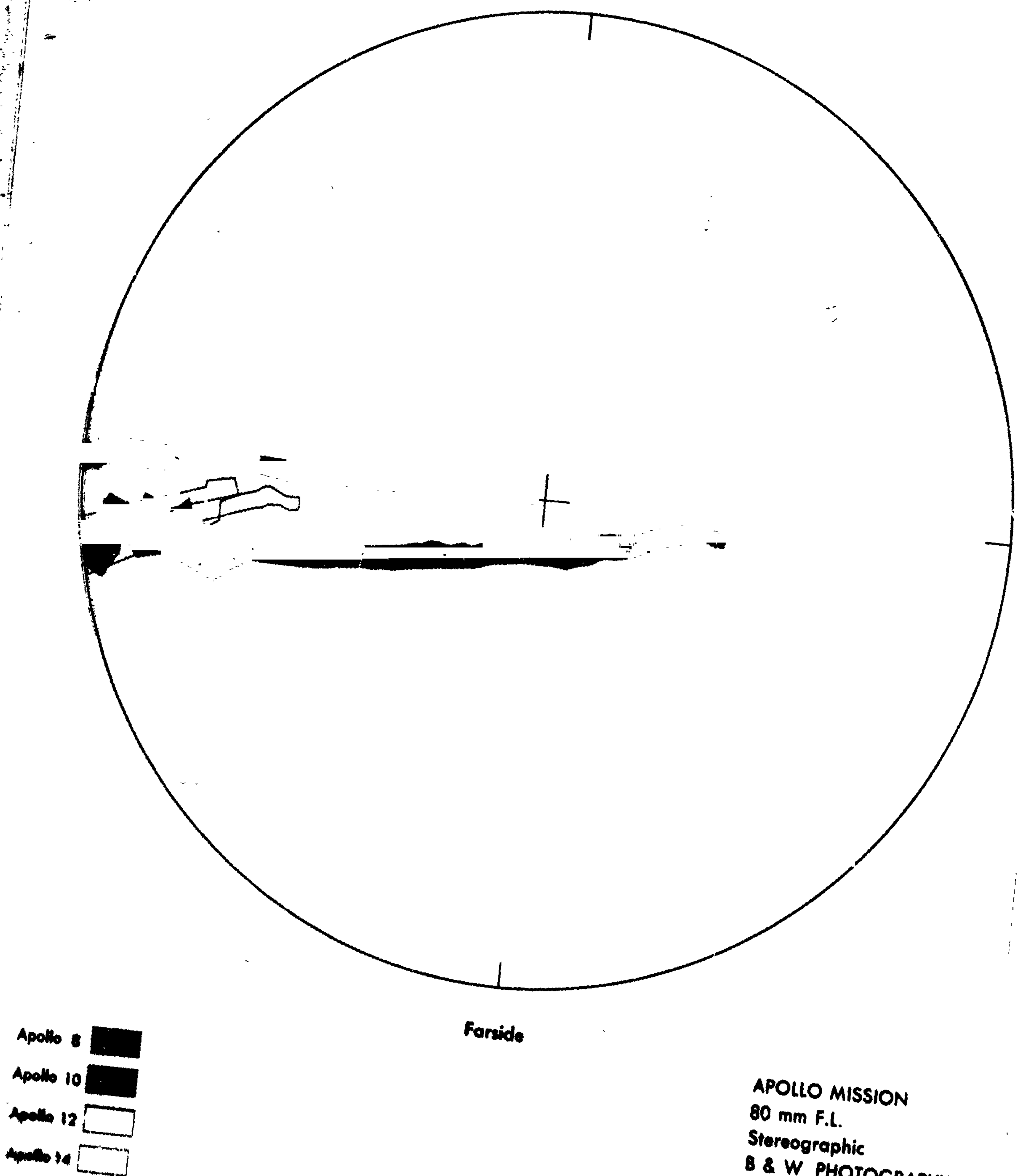


Farside

APOLLO MISSION
500 mm. F.L.
Oblique
COLOR PHOTOGRAPHY

Apollo 14

PHOTO INDEX NO. II (14)
Dec 1971

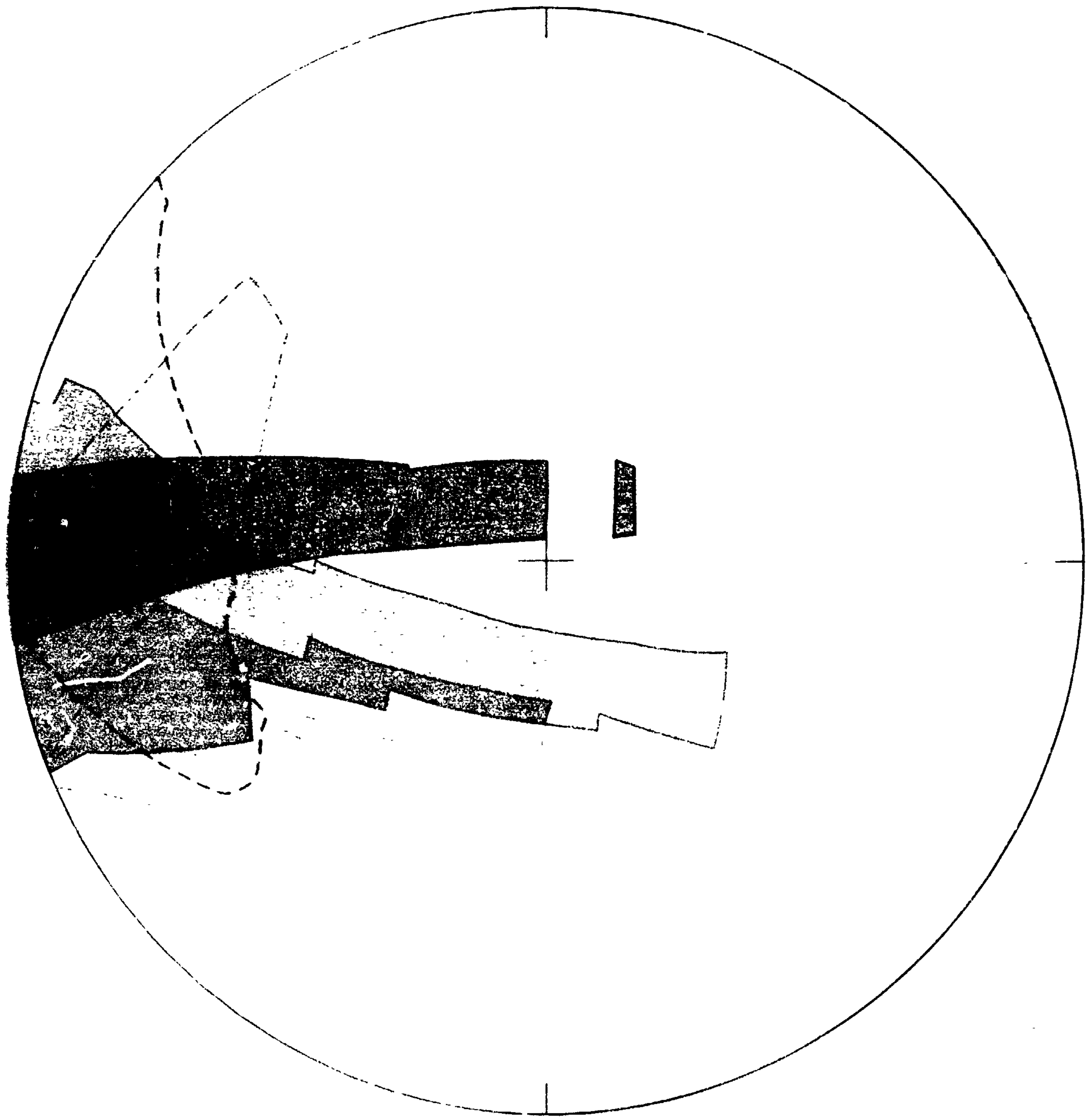


APOLLO MISSION
80 mm F.L.
Stereographic
B & W PHOTOGRAPHY

PHOTO INDEX NO. II (15)

Dec. 1971

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR



Farside

APOLLO MISSION
24'' Panoramic

B&W PHOTOGRAPHY

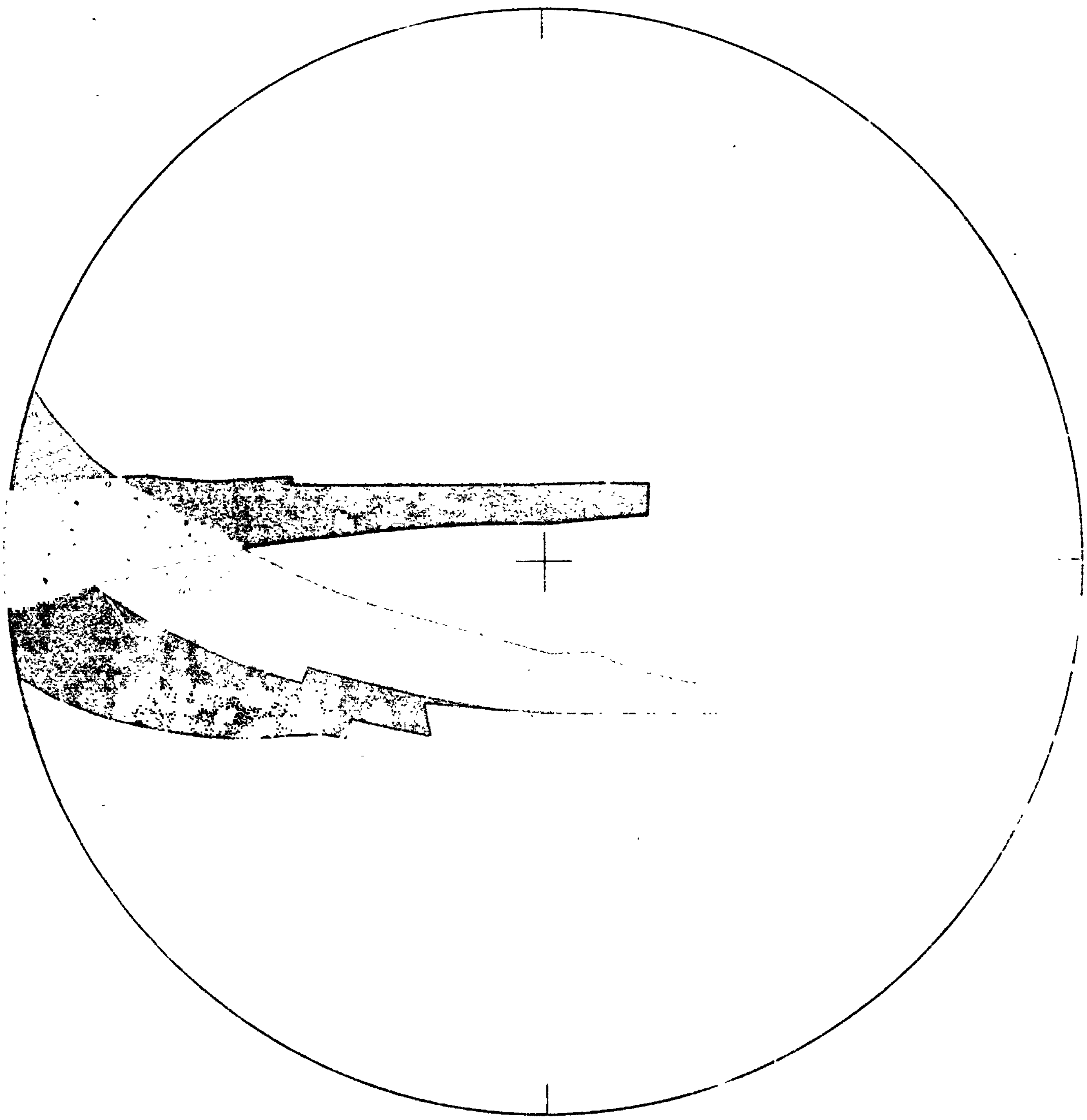
PHOTO INDEX NO. II (16)

July 1974

Apollo 15

Apollo 16 Transearth

Apollo 17

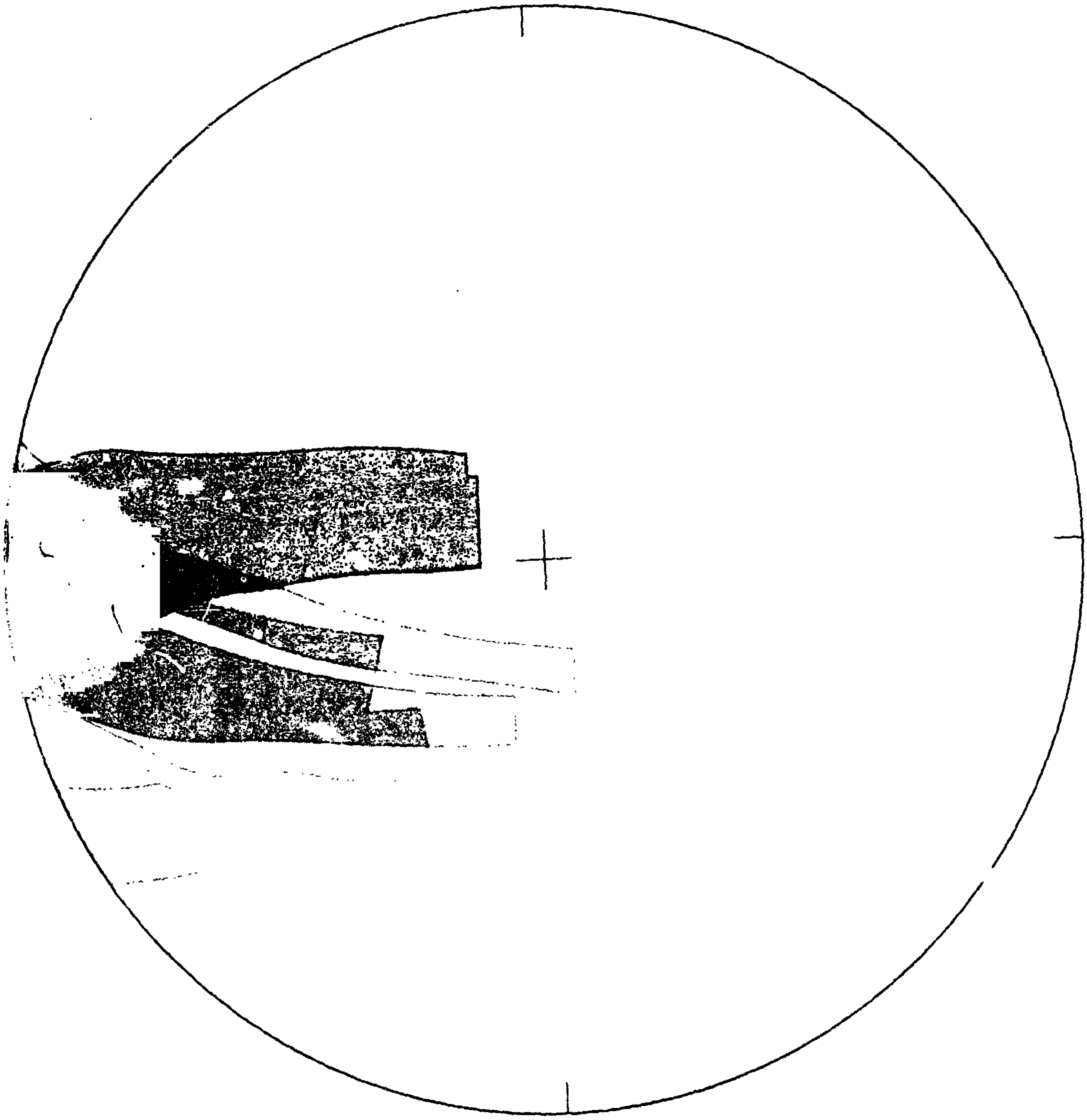


Farside

APOLLO MISSION
3" Mapping
Near Vertical
B&W PHOTOGRAPHY

A o 15
Apollo 16
Apollo 17

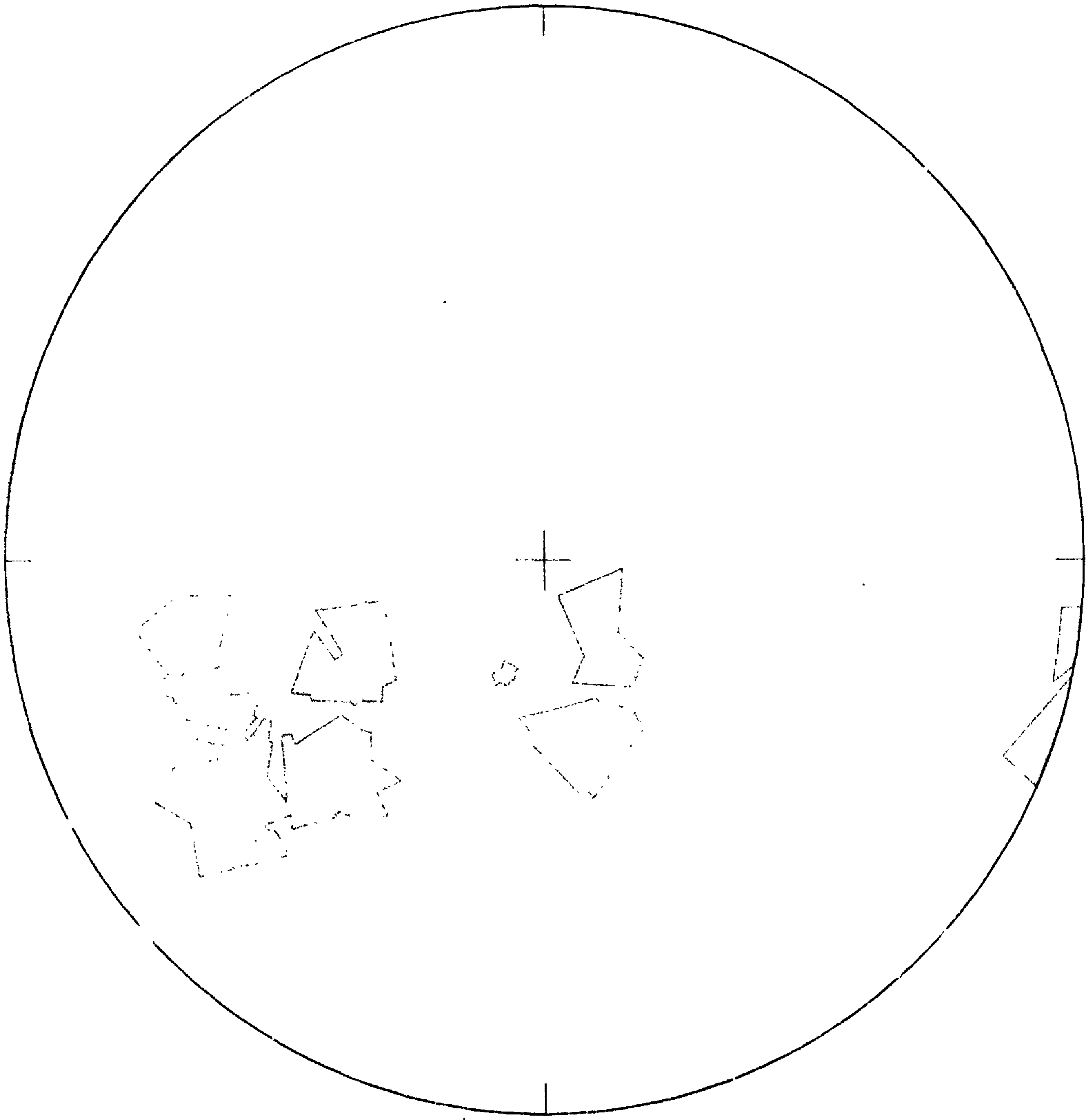
PHOTO INDEX NO. II (17)
July 1974



Farside

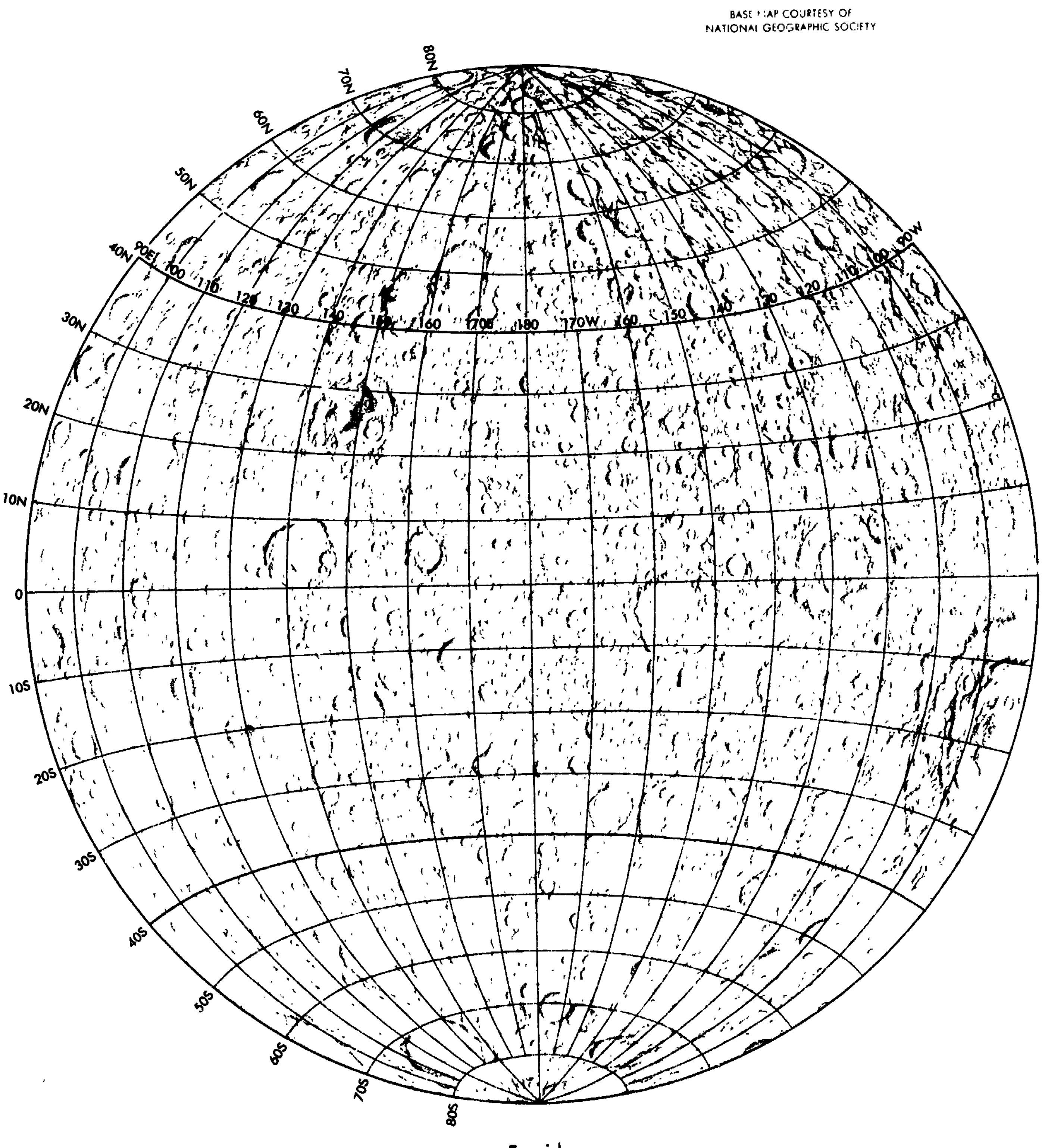
APOLLO MISSION
3" Mapping
Oblique
B&W PHOTOGRAPHY

PHOTO INDEX NO. II (18)
July 1974



Farside

APOLLO MISSION
55mm F.L.
Oblique
B &W and COLOR PHOTOGRAPHY



Farside

PHOTO INDEX BASE MAP NO. II

3.0 LUNAR CONTROL

The information required for establishment of precise lunar control systems is similar to earth requirements for defining geodetic datums. The datum's position and orientation must be fixed by a network of identifiable points based on a figure of computation having defined size, shape and relation to the lunar gravity figure. In view of the somewhat approximate state of our lunar scientific knowledges bearing on the moon's size, shape and gravity, it is not surprising that lunar control systems established to date fulfill some of the prescribed conditions with approximate data and are weak in relating widely separated lunar features. Lack of precision in our knowledge of the moon's size, shape and gravity figure are the principal error sources, with a smaller error contribution from inaccuracies in knowledge of the moon's motions as related to earth by existing ephemerides.

Prior to the advent of spacecraft in lunar proximity, lunar control was necessarily accomplished through earthbased telescopic photography and observations. Such control is, of course, restricted to the lunar nearside and limited in precision by the earth-moon distance and geometry. Earthbased lunar control solutions rely on reduction of heliometer observations to define the angles between Crater Mosting A and selected limb points. Computation of primary control points is based on the coordinates of Mosting A as the fundamental point, the known orientation, motion and center of mass of the moon with respect to earth and a correction model for atmospheric refraction. Earth-based lunar control systems designed to support cartographic work include the results of further mensuration of lunar full moon and phase photography and provide a network of positions and elevations for selected lunar features which are based on the primary points and size and orientation of lunar figure determined in the heliometer reduction.

More recent lunar control work has concentrated on development of systems based on observations and photography taken from lunar orbiting spacecraft. As the lunar center of mass is coincident with one of the focii of the spacecraft's orbit, control systems developed from orbital data have the distinct advantage of being mass centered rather than figure centered as in the earthbased telescopic case. The orbital method of establishing lunar control is dependent upon determining camera position and attitude relative to the lunar coordinate system and establishing lunar surface positions and elevations from the intersection of directed rays through photo image points appearing on two or more photographs. In effect, the datum of such control is established by the spacecraft ephemeris developed from earthbased radar tracking, with photogrammetry being employed to project orbital positions to the lunar surface. Camera attitude information results from stellar orientation which may be simultaneous with each lunar photograph or updated by changes in spacecraft orientation recorded by onboard inertial measurement unit. Some of the analytical photogrammetric programs used to establish lunar surface positions also achieve refinement of the orbital data by providing for adjustment in camera station positions within orbit, based on the computed compatability of position, attitude and photo measurement data.

The initial parameters for orbital photogrammetrically established lunar control systems are described by a set of Photo Support Data which defines camera position, attitude and related information for each photo exposure. The Photo Support Data values are the result of correlation of photo exposure time with developed orbit and attitude information. They are subject to specific conditions of lunar gravity model, planetary ephemeris and length of orbital arc data used in computation. Significant change in any of these elements and subsequent recomputation of photogrammetric solution will result in a change to the datum of the control system involved. Dossier section 2.6 describes editions of Photo Support Data that have served as a basis for lunar control development.

The accuracy of developed control systems is, of course, also dependent upon the fidelity of the photogrammetric solutions employed to derive lunar surface positions and elevations. Finite evaluations having a statistical basis are generally an end product of the computed photogrammetric solutions and are expressed relative to particular orbital mission ephemeral information as defined by Photo Support Data. Analytical photogrammetric triangulation programs such as HERGET, MUSAT, LOSAT and LOBAT have been used in computing lunar control. Each of the programs relies on input data in the form of space coordinates of exposure station, camera attitude and measurements of photo image points to reconstruct the conditions under which photography was taken and compute photo ray intersections determining the most statistically probable lunar surface positions and elevations. The programs differ principally in the sophistication with which data is treated and error analyses performed. The HERGET program only provides for individual photo strip solution and allows input or solution of the elements of camera position and orientation. MUSAT will handle photo strip and block solutions and provides for differential weighting and adjustment of the individual input parameters. LOSAT and LOBAT, designed for strip and block solutions respectively, apply the additional condition of constraining exposure station positions to lie on an orbital plane. The more recently developed SAPGO (Simultaneous Analytical Photogrammetric and Geodetic Observations) Program which provides increased computational efficiency, has been used in the development of large blocks of control from Apollo Mission 15-17 data.

Earthbased laser ranging to lunar based retroreflectors provides a new and important contribution to an absolute basis for Selenodetic System development. Continuing analysis and fitting of increasingly larger sets of ranging data to accepted lunar orbit, libration and mass distribution models is being performed. This work has resulted in precise definition of retroreflector positions with respect to the center of lunar mass and more importantly, provides a basis for development of improved lunar ephemeris and libration models.

3.1 GLOBAL CONTROL

The Global Control Systems discussed in this Section could perhaps better be described as hemispherical. With the exception of the Positional Reference System, which is primarily a lunar farside solution, they rely on earthbased telescopic photography accomplished during different lunar libration periods to provide a parallax differential as the basis for derivation of control point values. The coverage of these systems is necessarily restricted to the lunar nearside with degradation of latitude and longitude accuracies occurring as the lunar limb is approached.

Saunder 3.1.1

Franz & Schrutka (1958) 3.1.2

Baldwin 3.1.3

AMS (1964) 3.1.4

ACIC (1965) 3.1.5

DOD (1966) 3.1.6

Tucson (1968) 3.1.7

Kiev (1967) 3.1.8

Manchester (1967) (1971) 3.1.9

Positional Reference System (1969) (1974) 3.1.10

3.1.1 LUNAR CONTROL OF S. A. SAUNDER

The catalogue of Saunder lists the positions of 1433 features on the lunar surface. These were measured on four plates taken with the 24 inch Equatorial Coude of the Paris Observatory, 1895-99. They are gibbous photographs with both morning and evening terminators. For example, the first two plates measured were taken shortly after first quarter and shortly before last quarter. Therefore, the two plates have only a small area of the central portion of the lunar disc in common.

Plate constants for the first two positive plates were derived from a large number of points measured at the telescope. These included Mosting A and the eight fundamental points measured with the heliometer by J. Franz and nineteen features measured by Saunder. The latter were micrometric measurements made with a filar micrometer. Two of the fundamental points of Franz; Aristarchus, and Byrgius A, were deleted because of difficulty with their measurement on the plates. Plate constants for the negative plates included the determination of three additional features by Barnard with the 40 inch Yerkes refractor.

Measurements were made using a reseau and an astrographic micrometer with a scale in the eyepiece. The first attempt was to record the reseau on a positive copy of the lunar image. However, too much detail was lost in constructing the positive and as a result the reseau was clamped over the negatives. Each feature was measured four times, twice in opposite plate orientations.

At a later date, two plates taken with the 40 inch refractor at the Yerkes Observatory (1901) were measured by Saunder. These had been taken by G. W. Ritchey in an experiment to determine how much fine detail could be photographed under the best atmospheric conditions. Unfortunately, there is some question as to the actual dates of these photographs, which is necessary to lunar control studies. Saunder's analysis indicates that the listed date of one photograph is in error by one month and the other by one day. This casts considerable doubt on the value of these observations.

In all, 2885 points were measured and reduced on the Yerkes plates. These included the points previously observed on the Paris plates. This work served as the main basis for the catalogue of I.A.U. lunar coordinates by Blagg and Mueller (1935).

3.1.2 150 MOON CRATERS OF FRANZ & SCHRUTKA (1958)

The 150 moon craters measured by J. Franz are dispersed over the earthward hemisphere. Measurements were made on five plates taken with the 36 inch refractor at the Lick Observatory, 1890-91. These are primarily near full moon photographs and features were selected that stand apart from their surroundings due to their brightness. Although Franz referred to them as moon craters, a few bright mountain peaks are included in the list.

Plate constants were determined by Mosting A and the eight additional fundamental points that Franz derived with the heliometer. Measurements were made with an instrument built by Repsold for the Royal Prussian Academy of Sciences. It could only measure one coordinate precisely along the principal scale and this required that the plate be rotated. The X coordinate was measured twice in the 0 and 180 degree plate orientation, while the Y coordinate was measured with the plate rotated to 90 and 270 degrees. Because of the difficulty in measuring, Franz divided each plate into nine sectors that could be measured in one setting. Along with the features in each sector, the fundamental points were also measured. Thus, each sector was referenced to the lunar coordinate system as described by these fundamental points.

A new reduction of the 150 moon craters was made by Schrutka-Rechtenstamm (1958). This included a new computation of the eight fundamental points measured with the heliometer. The major basis for this new reduction was a better expression of the physical libration than was available to Franz. Also, Schrutka converted the sector measurements into a single set of observations for each plate. The measurements of Franz, as reduced by Schrutka, have been used as a basis for numerous following lunar control studies.

3.1.3 LUNAR CONTROL BY BALDWIN

The study of R. B. Baldwin developed a catalogue of coordinates for 696 features. These points were measured on five photographs taken with the 36 inch refractor at the Lick Observatory. Two of these plates are near first and last quarter, two others are crescent phase with morning and evening terminators, and one is at gibbous phase. Also, two of these plates are at almost identical librations and their measurements are correlated with regard to the selenographic reduction method.

This array of phase photography does not allow for multiple observations of individual features and the majority are measured on only two plates, the minimum requirement for a single determination of three-dimensional coordinates. The rest of the features are measured on two combinations of three different plates. Unfortunately, one of these combinations contains the two plates of almost identical libration.

Plate constants were derived using the 150 points of Franz as reduced by Schrutka. Due to the nature of the photography, different groups of points were used for each plate. As there were a relatively small number of points common to both systems, it was necessary to make small auxiliary corrections to the plate constants. The final computation of lunar heights was according to the scheme developed by Saunder.

3.1.4 AMS LUNAR CONTROL SYSTEM (1964)

The AMS Lunar Control System consists of two separate catalogues, AMS 1964 and Group NASA 1965. The AMS 1964 system lists the coordinates of 256 features dispersed over the moon's earthward hemisphere, while Group NASA lists 496 features concentrated in two zones or belts. These areas are 10 degrees north and south of the equator and 10 degrees east or west of the lunar prime meridian.

The number of control features in both of these catalogues was later reduced during their inclusion in the DOD Selenodetic Control System 1966. Two craters were removed from AMS 1964 because their derived heights exceeded 10 kilometers. A third fundamental adjustment was performed on Group NASA which deleted 805 observations equations and reduced the number of craters to 484.

Approximately the same set of photographs were used for both reductions. These were short exposures taken with the 36 inch refractor at Lick Observatory between 1930 and 1945. A great variety of phase angles are present including crescent and gibbous, with morning and evening terminators. A total of 19 plates were used for both reductions, 15 for AMS 1964 and 18 for Group NASA. Of these, 14 plates were common to both reductions.

Measurements were made by sessions rather than for an entire plate. A session refers to the measurement of a group of features in one day. In this manner, different groups of features appearing on a single plate were measured in various sessions. The AMS 1964 system was measured on 15 plates in 32 sessions, while the Group NASA contained 18 plates measured in 131 sessions. No attempt was made to convert the sessions on a plate into a single relative array of measured coordinates.

Therefore, plate constants, as such, were not determined. Instead, triangulation, rotation, and scale were derived for each session and a single plate may have several different values for these constants. The method of determining translation, rotation, and scale is by a least squares adjustment between the measurements of features in a session and their I.A.U. coordinates (Blagg and Muller, 1935).

3.1.5 ACIC SELENODETIC SYSTEM (1965)

The ACIC Selenodetic System lists coordinates for approximately 900 features dispersed over the moon's earthside hemisphere. Of these, 196 are primary positions and about 700 are supplementary or control extension points. A major purpose of this work was to furnish horizontal and vertical control for the ACIC lunar charting effort. These are the 1:1,000,000 scale LACs and the 1:500,000 scale AIC charts.

The primary control net was measured on near full moon photography taken at the Pic du Midi Observatory and the Naval Observatory at Flagstaff, Arizona. There were eight differently librated observations, of which seven are from Pic du Midi and one from the Naval Observatory. The Pic du Midi photography consists of a sequence of five short exposures, covering a very short period of time, for each observation. The Naval Observatory photography sets consist of three long exposures taken about one minute apart. All of the 196 primary points were measured on each plate in every sequence.

Plate constants were derived by a least squares transformation between the plate measurements and the projected positions of three selected features from the work of Schrutka-Rechtenstamm. Some of these coordinates were amended by the measured observations to derive a relatively consistent set.

The control extension was measured primarily on sequences of phase photography from Pic du Midi, along with some long exposures from the Naval Observatory. Generally, three sequences of photographs having approximately the same phase angle were used. These were selected so as to present the largest librational baselines between the three sequences. A select group of points were measured on every plate and features in the primary control net were used to develop plate constants.

Craters from three to twenty kilometers in diameter were measured, with the majority being less than ten kilometers in diameter. Most of the feature coordinates were determined from two or more sets of differently librated sequences. The control extension points are considerably denser in the equatorial region to support more intensive mapping requirements in this area.

3.1.6 DOD SELENODETIC CONTROL SYSTEM (1966)

The positions of 734 points are listed in this catalogue, which is a combination of the ACIC Selenodetic System (1965) and AMS Lunar Control System (1964) including Group NASA points (Reference Section 3.1.4). The method of reduction was basically the same as used in developing the AMS control. However, the DOD Selenodetic System does not provide an optimum combination of the ACIC and AMS control works.

3.1.7 TUCSON SELENODETIC TRIANGULATION (1968)

The Tucson Triangulation results in a catalogue that lists the position of 1355 features on the moon's earthward hemisphere. It combines the observations of three other control studies along with measurements of plates taken with the 40 inch refractor at Yerkes Observatory. These studies are the works of Saunder, ACIC, and Gavrilov (Kiev Triangulation).

This study consists of two distinct operations. The first is the determination of the positions of 48 features as measured on 25 star-trailed Yerkes Plates. Star trails and the position of Mosting A (Koziel, 1963) are used to determine orientation and translation that is independent of the heliometer observations of Franz. However, it was still necessary to derive scale from this system.

After the lunar image has been exposed, the telescope's drive is turned off and the trail of a star is recorded. This is used to determine celestial direction. A much larger group of star-trailed plates were to be used, but some difficulty developed in the processing. Normal lunar photographs were taken on the same nights as star-trailed plates and all were processed in the same manner. Since the star-trailed plates were open to the sky for a longer period of time, they were somewhat sky fogged and required a maximum contrast development. This was not done and rather poor quality images resulted.

The second operation was to determine the positions of the 1355 features from 37 differently librated observations. These included three Yerkes plates, six from Saunder, six from Gavrilov, and 22 from ACIC. It should be noted that the Gavrilov and ACIC systems use multiple plates per observation. Therefore, this work combines the measurements of the equivalent of 131 plates. The 48 positions from the star-trailed plates were used to establish translation, rotation and scale.

3.1.8 KIEV LUNAR TRIANGULATION (1967)

The Kiev study resulted in a "Catalogue of Selenocentric Positions of 500 Basic Points on the Moon's Surface." In this context, selenocentric refers to the center of mass and not the center of figure. This lunar study attempts to transform the origin of lunar positions to the center of mass after they have been determined in the normal manner. It is predicated on the fact that the librations actually occur about the center of mass and not the center of figure.

The observations were made with two different instruments. One was the astrograph (5.5 meters focal length) of the Main Astronomical Observatory, Goloseyevo. This instrument has an automatically moving plate holder which is used to obtain long exposures of 10 to 15 seconds. The purpose is to photographically average the uncorrelated trembling of the images caused by atmospheric turbulence. The second telescope is a 26 inch refractor of 10.5 meters focal length at the Pukovo Observatory. Often two or three photographs are taken at the same librational position and their measurements are combined.

The first effort was to develop a composite catalogue of the selenocentric coordinates of 160 base points. These points were measured on 16 near full moon plates taken at Goloseyevo and Pulkovo. They include the 150 features of the Schrutka system and 70 points measured in the Baldwin system. Plate constants were derived by a comparison of the measurements with the positions of ten features of the Schrutka catalogue. A composite catalogue was derived for the three different sources.

After these coordinates have been determined, corrections are derived to translate the origin from center of figure to the center of mass. Then, corrections are developed to convert the surface positions to "selenocentric" values. Since this adjustment depends on a feature's location, corrections were determined for local areas. The results of this study were used to establish the selenocentric coordinates of 500 basic points.

3.1.9 MANCHESTER SELENODETIC CONTROL SYSTEM (1967) (1971)

1. Manchester Selenodetic Control System (1967).

In the Manchester Triangulation, 906 features were measured on near full moon photography taken with the 24 inch Equatorial Coude at Pic du Midi Observatory (1960-66). There were 18 differently librated observations used in determining lunar positions. In the same manner as the ACIC control study, a sequence of short exposures were measured for each observation to reduce the effects of seeing displacements. This study used six exposures for each observation.

Features were selected for measurement that were small (5-6 kilometers) and could be identified on full phase photography. These included splash craters, mountain peaks, and other albedo points. The use of this type of photography was to eliminate the false positioning of a feature caused by different solar altitudes (phase effect). The actual measurements were primarily made with a Zeiss coordinate measuring instrument which has a reversible prism. This allowed a feature to be measured in the forward and reverse orientation without rotating the plate.

Plate constants were developed by a least squares transformation of the measured coordinates to the projected positions of known points. A higher order transformation is used to derive translation, rotation, scale and reduce the effects of atmospheric refraction. Terms beyond the first order are not used when the moon is photographed at small zenith distances. In all, 41 positions were used to determine plate constants. These were taken from the catalogues of Schrutka (1958) and ACIC (1965).

2. Manchester Selenodetic Control System (1971).

The 1971 publication of this System is based entirely on the observational data used in the 1967 System. Corrected values for 700 points were recomputed and published in Appendix II of Reference 3.4.20.

3.1.10 POSITIONAL REFERENCE SYSTEM (1969) (1974)

1. Positional Reference System (1969)

The Positional Reference System (1969) was designed to provide horizontal control for support of basic small scale mapping of the lunar farside. It was not intended to constitute a lasting selenodetic work and a catalog of positions was never produced for the System. Its positional results are best recorded in the Lunar Farside (LMP-2) and Polar Charts (LMP-3), scale 1:5,000,000 and Lunar Planning Charts (LOC), scale 1:2,750,000, which are described in Dossier Sections 4.1.1 and 4.1.3 respectively.

Essentially, the Positional Reference System extended the ACIC Selenodetic System of 1965 to the lunar farside through a system of overlapping perspective projections keyed to Lunar Orbiter Mission photographs, based on parameters provided by Mission Photo Support Data. Source data used was selected to obtain best area coverage and applicability to the 2.5-3 kilometer accuracy requirements of 1:5,000,000 scale mapping.

Twenty-four 3" focal length Lunar Orbiter Mission photographs were selected which approximately encircle the moon in polar and equatorial bands. The individual photographic segments (framelets) were precisely reassembled to calibrated values of the Lunar Orbiter film reseau. Perspective projections were computed for each selected photograph, based on camera focal length, position, and orientation. ACIC Selenodetic System (1965) points were plotted on the prepared projections in lunar nearside and limb areas. Each perspective projection was fitted to its reassembled base photograph, considering the fit to Selenodetic System (1965) points and the tie between overlapping photographs. The fitting of projections proceeded from the nearside to limb areas and by extension to the lunar farside where a join was effected in the central farside region with an indicated accuracy of 13 kilometers.

The graphic best fit technique employed in the development of the 1969 System sought the minimization of residual errors from spacecraft ephemeris, earthbased control points, camera orientation values and uncorrected photographic distortions. As might be expected, some differences exist in the positions defined by individual photographs and Positional Reference System values are a mean of these differences. Positions for lunar areas not covered by the polar and equatorial bands were obtained by the fitting of additional photography to these bands.

2. Positional Reference System (1974)

The Positional Reference System of 1974 was developed in continuance of the Positional Reference System (1969) objective of providing improved lunar farside horizontal positions in support of small scale mapping. Its development employed methodology which is similar to that described for the 1969 edition.

The principal basis for improvement in the 1974 version was incorporation of Apollo 15 Control System (Section 3.2.3.5) values and early results of triangulation with Apollo 16 photographs. This revision also reforms the polar and equatorial nets, used to extend control to the lunar farside and incorporates an Apollo 16 transearth photograph for improved tie of areas which were previously entirely dependent on Lunar Orbiter Mission I photographic coverage.

A density of horizontal positions of 1 point per 22,500 sq. kilometers is provided over the entire lunar surface with the exception of areas lacking photographic coverage. Photographic identifications of positioned features are also available. The evaluated accuracy of Positional Reference System (1974) positions ranges from 1-16 kilometers at 90% probability.

References 3.4.50 and 3.4.63 present more complete Positional Reference System information.

3.2 REGIONAL CONTROL

Establishment of lunar control on a regional basis has largely resulted from exploitation of data from individual lunar missions through the area of Apollo mission exploration (between 30° North and South latitudes).

Though limited in utility by the small number of points contained, The Laser Retroreflector System provides the most accurate set of positional data.

Apollo 15 and 17 Systems have greater application due to the more extensive areas covered with a high density of point positional data. Maximum coverage is provided by the Apollo 15 (April 1973) System which has been extended through the area of Apollo missions 15, 16, 17 vertical mapping photographic coverage to support near term control requirements for medium and large scale mapping. The enlarged area of coverage has been obtained at an early date with some sacrifice in the accuracy obtainable from component triangulation.

The Apollo 10 and 12 Systems are more limited in both coverage and accuracy and rely on the Landmark Tracking System for absolute positional basis.

Apollo Zone Triangulation (1969) 3.2.1

Landmark Tracking Control System 3.2.2

Apollo Mission Control Systems 3.2.3

Laser Retroreflector (1973) (1974) Systems 3.2.4

3.2.1 APOLLO ZONE TRIANGULATION (1969)

In 1968, the Manned Spacecraft Center initiated developmental triangulation work with Lunar Orbiter Mission IV photographic coverage of the lunar frontside equatorial region. Preliminary data produced in April 1969 to support small scale lunar charting constitutes the Lunar Orbiter IV Triangulation (1969) System. Work had been directed toward establishment of a unified control system covering the project Apollo Zone. Numerous independent local systems (Section 3.3.1, Control Indices I(4) and I(5)),covering Apollo sites have been established within the zone. Control Index No. I(1) diagrams the extent of coverage of the Lunar Orbiter IV (1969) System. The north-south projecting strips of coverage shown indicate the limited areas of stereoscopic coverage provided by high resolution photography obtained from consecutive Mission IV lunar orbital passes.

As in other experimental triangulation with Lunar Orbiter IV photography and Photo Support Data, results have been limited by the combined effect of high altitude and lack of precision in the photo support data values for camera orientation angles. Additionally, the work is affected by the aforementioned narrow sidelap between high resolution photos from adjacent orbits. The 1969 control data set consisting of approximately 3200 points extended from 75°W to 55°E with latitudinal coverage of up to ±20°. It employed control data from Site II-2, II-6, II-8, II-13 and III-11 area control systems (Section 3.3) in an attempt to strengthen the Lunar Orbiter IV triangulation with this data and evaluate the relationship of these individual systems.

This developmental triangulation work did not attain its objective of providing a precise unified control system covering the principal portion of the Apollo Zone.

3.2.2 LANDMARK TRACKING CONTROL SYSTEM

The Landmark Tracking Control System was initiated by NASA Manned Spacecraft Center in 1969 to assist in circumlunar navigation, provide a basis for extending control to the lunar farside, and for improvement of lunar nearside photogrammetric control solutions using Apollo Mission photography. Landmark tracking points established in earlier Apollo missions have been used in circumlunar navigation in later missions. Differences in coordinate values obtained through astronaut reobservation of the landmark points provided a basis for changing the Apollo spacecraft's orbital path to obtain an optimum orbit prior to lunar landing. The landmark system is unique among the orbital control systems in that spacecraft position is brought to the lunar surface through timed astronaut observations with spacecraft sextant and telescope rather than by photography. Positions for 19 landmarks (including 6 lunar farside points) have been developed. Lunar landmark point locations are shown in Control Indices I(2) and II(1).

Earthbased tracking information, spacecraft observations and defined line of sight with respect to spacecraft inertial measurement provide basic data. Jet Propulsion Laboratory's Planetary Ephemeris 19 (DE-19) and NASA/MSC Gravity Model L1 were used in orbit reduction. Orbital positions are based on data arcs of two orbit duration for lunar farside points and single nearside arcs for lunar nearside points. A series of landmark tracking observations was performed on Apollo Missions 8, 10, 11, 12, 14 and 15.

The evaluated accuracy of landmark tracking points is in the order of 900 meters horizontally and 400 meters vertically (1 sigma) with prime error contribution from the inadequate lunar gravity model available for use in computation of their positions. The landmark tracking points constitute the most accurate data presently available for relating widely separated points in the lunar equatorial region, though their utility is restricted by the small number of points (19) currently available. Further information on the development of the Landmark Tracking System, including individual point identification and evaluation, is contained in reference 3.4.1.

3.2.3 APOLLO MISSION CONTROL SYSTEMS

Developmental triangulation with Apollo Mission 8 photography was initiated at the NASA Manned Spacecraft Center (MSC) in 1969. Further lunar control data has been generated by MSC, ACIC, TOPOCOM and Duane Brown Associates using Apollo Missions 10, 12 and 14 80mm focal length photography and Photo Support Data in concert with selected Landmark Tracking Control Points.

These triangulation projects were performed with the objectives of defining the accuracy with which control values could be determined with the mission photo system, extending the Landmark Tracking Control System, defining relationships with other control systems and providing control values to support map compilation in areas of requirement.

Results obtainable in these works are limited by the non-photogrammetric characteristics of the mission photography and lack of recorded time of photo exposure, preventing direct and precise correlation with Mission Photo Support Data. These control systems rely on imaged Landmark Tracking Points (Section 3.2.2) to relate photography and Photo Support Data and establish control system scale and absolute position.

Apollo 15-17 Control System development through analytic photogrammetric triangulation, has been accomplished to support lunar mapping, provide improved definition of selenodetic parameters and contribute to development of an improved selenodetic system. Apollo Missions 15, 16 and 17 photography and related data has provided source materials which are vastly more suitable to control development than data available from earlier Apollo missions. The Metric Camera System photography has excellent photogrammetric characteristics, exposure time was recorded to .001 second allowing precise correlation to Apollo spacecraft ephemerides, facility for accurate determination of camera orientation is provided by companion stellar photography and maintenance of consistent scale in triangulation solutions is facilitated by accompanying laser altimetry.

Apollo 10 (1970) Nearside System 3.2.3.1

Apollo 10 (1970) Farside System 3.2.3.2

Apollo 12 (ACIC-1971) System 3.2.3.3

Apollo 12 (TOPOCOM-1971) System 3.2.3.4

Apollo 15 (April and November 1973) Systems 3.2.3.5

Apollo 17 (1974) System 3.2.3.6

3.2.3.1 APOLLO 10 NEARSIDE SYSTEM (1970)

The Apollo 10 Nearside System (1970) was produced by ACIC in September 1970. It is composed of some 333 points and consists of a strip along the lunar equator from 30° - 42° East Longitude. Its coverage is diagrammed in Control Index No. I(3).

The LOSAT analytical triangulation program was used to compute strip triangulation solutions with Mission 10 Hassleblad camera 80mm focal length Magazine 0 frames 4029-4048, overlapping Magazine R frames 4525-4528, 4535-4539 and preliminary Apollo Mission 10 Photo Support Data. Landmark Tracking Points (Section 3.2.2) B-1 1/10, B-1/8 and 130 1/10 were identifiable on Magazine R exposures.

An initial LOSAT computation of Magazine R frames 4025-4539 demonstrated inconsistency between photo measurements and support data in central exposures of the strip and final computation only employed Magazine strip R segments containing the Landmark Points. Magazine R and 0 strip solutions were developed which are consistent with the longitude positions of the Landmark Tracking points. Under this condition systematic variances of 800-1800 meters in latitude were exhibited between accepted and derived Landmark Tracking Point values.

The LOBAT program was used to block the Magazine R and 0 strips together, holding Landmark Control points to within their evaluated accuracy. The accuracy (90% probability) of developed positions and elevations was evaluated at 75 meters and 120 meters respectively, relative to the datum defined by the Landmark Tracking and preliminary Photo Support Data.

3.2.3.2 APOLLO 10 FARSIDE SYSTEM (1970)

The Apollo 10 Farside System (1970) was produced by Duane Brown Associates in November 1970. It consists of a strip along the equator from 105° - 177°E longitude, as diagrammed in Control Index No. II(2).

The SURBAT Analytical Triangulation Program was used to compute a strip triangulation solution with Mission 10 Hassleblad camera 80mm focal length Magazine 0 frames 4060-4131 and preliminary Apollo Mission 10 Photo Support Data. Landmark Tracking Points (Section 3.2.2) CP-1/10 and CP-2.10 are imaged on Magazine 0 exposures.

The strip solution was developed to be consistent in longitude with the Landmark Tracking Points without constrainment to their positions. Under this condition, a variance of 200-1800 meters in latitude was exhibited between accepted and derived Landmark Tracking Point Values.

3.2.3.3 APOLLO 12 (TOPOCOM-1971) SYSTEM

The Apollo 12 (TOPOCOM-1971) System was produced in July 1971. It comprises some 770 points and extends from 24°E to 20°W longitude along the 7°South parallel. Its coverage is diagrammed on Control Index No. I(3).

The LOSAT analytical triangulation program was used to compute a strip triangulation solution with Mission 12 Hassleblad camera - 80mm focal length Magazine T frames 8044-8087 and Apollo 12 Mission Photo Support Data. Frames 8044-8053 are common to the ACIC-1971 system. Landmark Tracking Control Points DE1-12 and FM1-12 were identified on Magazine T exposures. Included in the triangulation were Lunar Orbiter III Site Control Points, Apollo Zone Triangulation (1969) System Points, and Earthbased Control Points.

The utility of the developed control system is limited by the poor resolution of photographic detail present in segments of the Apollo 12 photography and the position and scale of the strip solution relative to the two landmark tracking control points. The control system is positioned north and east of given values for the Landmark Tracking Control Points and computed at a smaller scale. Differences exhibited between the given and computed (Landmark Control Solution) values exceed the assigned evaluations of points DE1-12 (latitude) and FM1-12 (longitude and height).

The Apollo 12 Nearside (TOPOCOM - July 1971) Control System was established with respect to the datum defined by the Mission Apollo 12 Photo Support Data and the Landmark Tracking points, but is not consistent with the Landmark Control. The system has an evaluated horizontal accuracy (90% probability) of 283 meters and vertical accuracy (90% probability) of 293 meters.

3.2.3.4 APOLLO 12 (ACIC-1971) SYSTEM

The Apollo 12 (ACIC-1971) System was produced in July 1971. It is composed of 659 points and extends from 59° to 14° east longitude along the 10° south parallel. Its coverage is diagrammed on Control Index No. I(3).

The LOSAT Analytical Triangulation Program was used to compute the strip triangulation solutions with Mission 12 Hassleblad camera 80mm focal length Magazine T frames 8012-8053, overlapping Magazine EE frames 8180-8200 and Apollo Mission 12 Photo Support Data. Landmark Tracking Points CP 2-12 and DE 1-12 were identified on Magazine T exposures and CP 2-12 on Magazine EE exposures. MSC Lunar Orbiter IV Triangulation (1969) System points and Earth-Based Control Points were included.

The accuracy and utility of the developed control system is limited by the poor resolution of photographic detail present in these segments of Apollo 12 photography and the existence of only one identifiable Landmark point on Magazine EE exposures. The single Landmark point contained in strip EE did not allow adequate definition of this orbit and systematic variances of up to 4000 meters are exhibited with respect to the Magazine T solution. The Landmark controlled Magazine T LOSAT solution is considered to represent the most valid set of control data produced on the datum of the CP 2-12 and DE 1-12 Landmark Tracking Points. This solution was developed consistent with the positions of the Landmark Tracking points to within 383 meters in latitude, 209 meters in longitude and 130 meters in height.

Comparison of the given and derived (Orbit Constrained Solution) values of Landmark Tracking Points provided a basis for evaluating the compatability of Mission Photo Support Data and Landmark Tracking. Magazine T Orbit Constrained Solution locates these points 800 to 2100 meters north of their given position.

3.2.3.5 APOLLO 15 (APR & NOV 1973) SYSTEMS

1. Apollo 15 (Apr 1973) System

This initial Apollo 15 Control System was developed by DMAAC with the SAPGO (Simultaneous Adjustment of Photogrammetric and Geodetic Observations) program, and was designed to support lunar mapping programs being undertaken at that time. In its original form the System extended from 174° east to 64° west longitude in the area of Apollo 15 vertical photographic coverage.

Triangulation of each of the 14 vertical photographic orbital arcs of Apollo 15 mapping photography was performed to facilitate evaluation of spacecraft ephemeral information contained in Mission Photo Support Data. Camera orientation values were computed with the SATLUM Program, based on measurements of stellar photography. In deriving coordinate values for control points, a SAPGO photogrammetric block solution was developed which was constrained (200 meters horizontally and 50 meters vertically) to Photo Support Data's definition of orbital revolution 44 camera station positions. Laser altimetry was applied as a constraint in the area east of 140 degrees east longitude.

In a March 1974 continuation of mapping support, DMAAC extended this control system to the area of Apollo 16 vertical photogrammetric coverage through a SAPGO triangulation which was based on preliminary Apollo 16 Photo Support Data and previously established Apollo 15 System control points.

Further extension and intensification of the Apollo 15 (Apr 73) System in support of mapping was also accomplished by DMATC during 1974. Apollo 17 metric oblique photography was used to extend control to the area of the Russian Lunachod II's explorations and to provide an increased density of points through triangulation of Apollo Mission panoramic photography.

Additional extension of the Apollo 15 (Apr 73) System through the additional area of Apollo 17 vertical mapping photographic coverage was accomplished by DMAAC in February 1975. This extension was also designed to support lunar mapping activity.

The accuracy of the initial Apollo 15 (Apr 1973) System Control Points is evaluated at 35 meters horizontally and 40 meters vertically (90% probability) with respect to its established datum. In the area of its extension through Apollo 16 photographic average, accuracy is progressively degraded with respect to the established datum to [illegible]00 meters (horizontal) and 200 meters (vertical) at the easternmost extension and 1100 meters (horizontal) and 400 meters (vertical) at the westernmost extension. In the extension area through Apollo 17 vertical photographic coverage, accuracy with respect to the Apollo 15 (Apr 1973) Datum is progressively degraded to within a horizontal range of 300-400 meters and a vertical range of 150-400 meters expressed at 90% probability.

A density of one control point for 900 sq. kilometers is maintained through the System's area of coverage, which is diagrammed in Control Indexes I(3a) and II(3). These indexes also depict areas where an increased density of control points have been generated to support mapping at larger scales. References 3.4.53 and 3.4.54 provide additional information on basic development of the Apollo 15 System. Reference 3.4.62 discusses control intensification activity.

2. Apollo 15 (Nov 1973) System

This recomputation of the April 1973 version of the Apollo Control System by DMAAC employed the same photographic and ephemeral data, but constrained the photogrammetric block solution to all laser altimetry available from Apollo Mission 15. While individual control point accuracies are only slightly improved from earlier developed values, the improved scale of this solution provides a more accurate relationship between widely separated points. Data from the Apollo 15 (November 1973) System has been used to support selenodetic studies.

Lunar coverage of the Apollo 15 (Nov 1973) System is confined to the area of Apollo 15 vertical photographic coverage and is reflected in Control Indexes I(3b) and II(4).

3.2.3.6 APOLLO 17 (1974) SYSTEM

The Apollo 17 System was developed by DMAAC in April 1974 as a by-product of Apollo Control System development. It serves as an interim system to positionally relate lunar features within the area of Apollo 17 vertical photographic coverage, extending 247 degrees in lunar longitude from 42° west to 155° west.

Triangulation of 5 complete Apollo 17 orbital photographic revolutions and portions of 3 additional revolutions was performed with the SAPGO (Simultaneous Adjustment of Photogrammetric and Geodetic Observations) Program using Apollo 17 vertical mapping photography. Triangulated photography was selected for its additional coverage to Apollo 15 and 16 photographs and to facilitate evaluation of spacecraft ephemeral information contained in Mission 17 Photo Support Data. Camera orientation values were computed with the SATLUM Program, based on measurements of stellar photography.

In deriving coordinate values for control points, a SAPGO Program photogrammetric block solution was developed which was constrained to Mission Photo Support Data's definition of camera station position as indicated in the following table. The photogrammetric solution was also constrained to Mission 17 laser altimetry.

Orbital Photographic Revolution	Constraint Along Each Coordinate Axis in Meters
2	1500
14	500
29	300
38	100
49 (partial)	500
62 (partial)	100
66 (partial)	100
74	100

The accuracy of Apollo 17 System control points is evaluated at 45 meters horizontally and 35 meters vertically (90% probability) with respect to its established datum. Approximately 900 Apollo 17 System control points are common to the Apollo 15 Control Systems and generally reflect systematic differences of 600 meters horizontally and 200 meters vertically between the established Apollo 15 and Apollo 17 Datums.

A density of one control point per 900 sq. kilometers is maintained through the System's area of coverage, which is diagrammed in Control Indexes I(3b) and II(4). References 3.4.57 and 3.4.58 provide further Apollo 17 System information.

3.2.4 LASER RETROREFLECTOR (1973) (1974) SYSTEMS

1. The Laser Retroreflector (1973) System

The Laser Retroreflector (1973) System resulted from the establishment of a laser ranging system at the McDonald Observatory, University of Texas and continuing analyses of ranging data by contributing scientists from Jet Propulsion Laboratory, National Bureau of Standards, Air Force Cambridge Research Laboratories, University of Texas, University of California and NASA.

The four sets of lunar coordinates located at the Apollo 11, 14 and 15 landing sites and the Russian Lunakhod II retroreflector (Index I(3c)) are considered to provide the most accurate absolute relationship to the lunar center of mass. Coordinates are available in terms of both lunar axes of rotation and principal axes, resulting from ranging data having an accuracy of 15-30 centimeters. They are based on use of the LURE I lunar ephemeris which was also developed through analyses of laser ranging data.

Available coordinates are the result of early analysis of limited quantities of data. The positional relationship between the Apollo reflectors is evaluated as being accurate to within 50 meters with the exception of longitude value of the Apollo 15 reflector whose accuracy is evaluated at 230 meters.

Further information is provided in references 3.4.59-3.4.61.

2. The Laser Retroreflector (1974) System

The Laser Retroreflector (1974) System provides refined coordinates for each of the retroreflectors comprising the 1973 System. It has resulted from continuing analysis of 5 years of laser ranging and is based upon the improved LURE 2 lunar ephemeris.

The absolute accuracy of 1974 System Apollo reflector positions is evaluated at 52 meters and uncertainty in the distances between the reflectors is estimated to be 22 meters. Due to the much smaller amount of ranging data available for Lunakhod II, uncertainties associated with coordinates for this reflector are estimated to be twice as great.

3.3 LOCAL CONTROL

Local lunar control systems have been developed primarily to support mapping and study of potential and selected lunar landing sites and sites of scientific interest. In addition, positional data has been produced as a by-product of projects designed to test and evaluate the consistency and inter-orbit relationship of Mission Photo Support Data.

In general, established local control systems have been obsoleted by regional systems developed from Apollo mapping photography (Sections 3.2.3.5 and 3.2.3.6). The local systems have continuing value only in areas not covered by the more accurate regional systems or where they are based on larger scale photography and provide more precise relative positional data.

Lunar Orbiter Based Systems 3.3.1

Apollo Based Systems 3.3.2

3.3.1 LUNAR ORBITER BASED SYSTEMS

Limited accuracy in knowledge of Lunar Orbiter Mission camera orientations and inability to precisely correlate exposure time to Mission Photo Support Data, prevented development of control systems having continuity over large areas of the moon. The initial exploitation of Lunar Orbiter Mission photographs for control development purposes resulted in the following described local systems which generally provide accurate relative positional relationships within their individual areas of coverage.

Site I-1 (1967) 3.3.1.1

Site I-2 (1967) 3.3.1.2

Site I-3 (1967) 3.3.1.3

Site I-4 (1967) 3.3.1.4

Site I-5 (1967) 3.3.1.5

Site I-7 (1967) & (1969) 3.3.1.6

Site I-8 (1967) 3.3.1.7

Site I-9 (1967) 3.3.1.8

Site II-2 (1967) & (1968) 3.3.1.9

Site II-6 (1967) & (1969) 3.3.1.10

Site II-8 (1967) (1969) & (1971) 3.3.1.11

Site II-11 (1967) 3.3.1.12

Site II-13 (1967) & (1968) 3.3.1.13

Site III-1 (1968) 3.3.1.14

Site III-7 (1969) & (1971) 3.3.1.15

Site III-9 (1967) & (1969) 3.3.1.16

Site III-10 (1968) 3.3.1.17

Site III-11 (1967) & (1968) 3.3.1.18

Site III-12 (1967) & (1968) 3.3.1.19

Site V-11 (1968) 3.3.1.20

Site V-16 (1969) 3.3.1.21

Site V-27 (1969) & (1971) 3.3.1.22

Site V-31 (1971) 3.3.1.23

Site V-42 (1968) 3.3.1.24

Alphonsus (1971) 3.3.1.25

Aristarchus (1969) 3.3.1.26

Censorinus (1968) 3.3.1.27

Copernicus (1969) 3.3.1.28

Fra Mauro (June 1969) & (Oct 1969) 3.3.1.29

Gassendi (1969) 3.3.1.30

Hipparchus (1969) 3.3.1.31

Marius F (1969) 3.3.1.32

Mosting C (1969) 3.3.1.33

Prinz (1969) 3.3.1.34

Rima Hadley (1970) 3.3.1.35

Rima Hyginus (1969) 3.3.1.36

Rimae Littrow (1969) & (1970) 3.3.1.37

Rima Bode II (1969) & (1971) 3.3.1.38

Tycho (1971) 3.3.1.39

3.3.2 APOLLO BASED SYSTEMS

The suitability of Apollo mapping camera photographs and Photo Support Data for control determination has enabled development of regional control systems through the area of Apollo photographic mapping coverage. Local control systems based on Apollo photography have only been produced when the regional systems were unavailable to satisfy priority requirements.

Descarte (1971) 3.3.2.1

Taurus Littrow (1972) 3.3.2.2

3.3.1.1 SITE I-1 (1967) SYSTEM

The Site I-1 (1967) Control System was produced by TOPOCOM in April 1967 to support lunar site mapping. It is composed of some 1600 points and is located at 0 45'S and 42 00'E with coverage as indicated on Control Index No. I(4).

The LOSAT Program was used to develop site control points with Lunar Orbiter Mission I medium resolution exposures 52-55, 58, 61, 64-67 and preliminary Photo Support Data dated November 1966. The I-1 System was produced with an evaluated horizontal accuracy (90% probability) of 202 meters and vertical accuracy (90% probability) of 529 meters relative to the datum defined by the preliminary Photo Support Data. Control points related to the DOD Selenodetic System (1966) were included in this triangulation. However, the limited weight given them did not allow them to significantly affect the solution.

3.3.1.2 SITE I-2 (1967) SYSTEM

Site I-2 (1967) Control System was produced by TOPOCOM in December 1967 to support site mapping. It is composed of some 1480 points and is located at 0°0' 35°30'E with coverage as indicated in Control Index No. I(4).

The LOSAT analytical triangulation program was used to develop site control points with Lunar Orbiter I medium resolution exposures 68-71, 74, 77, 80-83 and preliminary Photo Support Data. The I-2 system was produced with an evaluated horizontal accuracy (90% probability) of 142 meters and vertical accuracy (90% probability) of 200 to 600 meters relative to the datum defined by the preliminary Photo Support Data.

3.3.1.3 SITE I-3 (1967) SYSTEM

Site I-3 (1967) Control System was produced by TOPOCOM in March 1967 to support site mapping. It is composed of some 75 points and is located at 0°30'N and 26°0'E with coverage as indicated in Control Index No. I(4).

The LOSAT analytical triangulation program was used to develop site control points with Lunar Orbiter I medium resolution exposures 85-88, 91, 94, 97-100, and preliminary Photo Support Data. The I-3 system was produced with an evaluated horizontal accuracy (90% probability) of 338 meters and vertical accuracy (90% probability) of 605 meters relative to the datum defined by the preliminary Photo Support Data. Points related to the DOD Selenodetic System (1966) were included in the LOSAT computation and reflected an average 5 km difference between positions based on the orbital ephemerides. The limited weight given these DOD earthbased points did not allow them to significantly affect the solution.

3.3.1.4 SITE I-4 (1967) SYSTEM

Site I-4 (1967) Control System was produced by TOPOCOM in December 1967 to support site mapping. It is composed of some 1440 points and is located at 0°0' 13°30'E with coverage as indicated in Control Index No. I(4).

The LOSAT analytical triangulation program was used to develop site control points with Lunar Orbiter Mission I medium resolution exposures 105-112 and preliminary Photo Support Data dated November 1966. The I-4 system was produced with an evaluated horizontal accuracy (90% probability) of 99 meters and vertical accuracy (90% probability) of 100-250 meters relative to the datum defined by the preliminary Photo Support Data.

3.3.1.5 SITE I-5 (1967) SYSTEM

The Site I-5 (1967) Control System was produced by ACIC in January 1967 to support site mapping. It is composed of some 140 points and is located at 0°N and 1°30'W with coverage as indicated in Control Index No. I(4).

The HERGET analytical triangulation program was used to develop site control points with Lunar Orbiter Mission I medium resolution exposures 118, 121, 124, 127, 130, 133 and Preliminary Photo Support Data dated November 1966. Acceptable compatability between photo measurements and Photo Support Data was not achieved and apparently level lunar surface points were held at a common elevation (a lunar radius vector of 1738 km) to influence the solution. Horizontal coordinates derived from the HERGET photo assembly were transformed to the DOD Selenodetic System (1966) by adjustment to six earthbased control points whose values in the DOD system had been established.

The I-5 System was produced with an evaluated horizontal accuracy of 375 meters (90% probability) relative to the DOD selenodetic System (1966) and a vertical accuracy of 150 meters (90% probability) relative to the assumed vertical datum.

In view of the early and approximate Photo Support Data used, its amalgamation with earthbased control and the necessity for use of an arbitrary vertical datum to achieve a realistic solution, the I-5 System is considered to be of marginal value. Utility is limited to definition of relative elevation and position differences.

3.3.1.6 SITE I-7 (1967) AND (1969) SYSTEMS

1. Site I-7 (1967) Control System was produced by TOPOCOM in August 1967 to support site mapping. It is composed of some 70 points and is located at 3°15'S 22°0'W with coverage as indicated on Control Index No. I(4).

The LOSAT analytical triangulation program was used to develop site control points with Lunar Orbiter I medium resolution exposures 157-160, 163, 166, 169-172 and preliminary Photo Support Data. The I-7 System was produced with an evaluated horizontal accuracy (90% probability) of 202 meters and vertical accuracy (90% probability) of 513 meters relative to the datum defined by the Preliminary Photo Support Data. Points related to the DOD Selenodetic System (1966) were included in the LOSAT computation. However, the limited weight given these points did not allow them to significantly affect the solution.

2. The I-7 Surveyor III (1969) System was produced by TOPOCOM in February 1969 to support mapping of the Surveyor III site area. Some 55 points are included in the control system located at 3°12'S and 23°23'W.

The LOSAT and MUSAT analytical triangulation programs were used to develop control points with Lunar Orbiter medium resolution exposures 157-160, 163, 166, 169-172 (I-7) and high resolution exposures 137, 154 (III - 9b and 9c). The high resolution exposures were combined with the I-7 (1967) System which also defines the datum of the Surveyor III System.

3. Site I-7 (1969) System was produced by TOPOCOM in September 1969 in support of the Apollo Mission 12 landing. It consists of some 460 points. Apollo 12 points and the Surveyor III spacecraft image were included in the triangulation. The I-7 (1969) System was based on a LOSAT analytical triangulation solution which employed the same photography as used in the 1967 system and Photo Support Data dated October 1968.

4. The Site I-7 Apollo Landing (1969) System was produced by TOPOCOM in September 1969 through the combination of the I-7 (1969) System with Orbiter III - 9b and 9c strip triangulation solutions accomplished in production of the I-7 Surveyor III (1969) System. This single system was established using the LORMS program to combine individual strip solutions.

3.3.1.7 SITE I-8 (1967) SYSTEM

The Site I-8 (1967) Control System was produced by TOPOCOM in July 1967 to support site mapping. It is composed of some 840 points and is located at 3°S and 36°30'W with coverage as indicated in Control Index No. I(4).

The LOSAT analytical triangulation program was used to develop site control points with Lunar Orbiter I medium resolution exposures 76-83 and preliminary Photo Support Data. Points related to the DOD Selenodetic System (1966) were included in the LOSAT computation. However, the limited weight given these points did not allow them to significantly affect the solution. The accuracy of this control system is unevaluated.

3.3.1.8 SITE I-9 (1967) SYSTEM

Site I-9 Control System was produced by ACIC in January 1967 to support lunar site mapping. The triangulation contains some 175 points and is located at 1°30'S and 43°12'W (Control Index No. I(4)).

Individual photo strip assemblies were computed with the HERGET analytical triangulation program for Lunar Orbiter medium resolution frames 184, 187, 190, 193, 196, 199 of photo strip 9.2a and 200, 203, 206, 209, 212, 215 of overlapping strip 9.2b. Photo Support Data, dated November 1966, provided initial camera position and orientation data. Acceptable compatability between photo measurements and Photo Support Data was not achieved and apparently level lunar surface points were held at a common elevation (a lunar radius vector of 1738 km) to influence the solution. The lunar surface positions derived from the two photo strips exhibited systematic horizontal differences of approximately 2 km and strips were combined by enforcing a following HERGET solution to an average of the individual strip differences. Horizontal coordinates derived from the HERGET photo assembly were transformed to the DOD Selenodetic System (1966) by adjustment to six supplemental earthbased control points whose values in the DOD System had been established.

The I-9 System was produced with an evaluated horizontal accuracy of 1615 meters (90% probability) relative to the DOD 66 Earthbased Datum and a vertical accuracy of 200 meters (90% probability) relative to the assumed vertical datum.

3.3.1.9 SITE II-2 (1967) AND (1968) SYSTEMS

1. Site II-2 (1967) System.

The Site II-2 (1967) Control System was produced by TOPOCOM in August 1967 to support site mapping. It is composed of some 1060 points and is located at 2°30'N, 34°0'E with coverage as indicated in Control Index No. I(4).

The LOSAT analytical triangulation program was used to develop site control points with Lunar Orbiter Mission II medium resolution exposures 35-42 and preliminary Photo Support Data dated February 1967. The II-2 system was produced with an evaluated horizontal accuracy (90% probability) of 66 meters and vertical accuracy (90% probability) of 100-150 meters relative to the datum defined by the preliminary Photo Support Data. Points related to the DOD Selenodetic System (1966) were included in the LOSAT computation. However, the limited weight given these points did not allow them to significantly affect the solution.

2. Site II-2 (1968) System.

The Site II-2 (1968) System was produced by TOPOCOM in December 1968 to provide basic information bearing on the consistency of Photo Support Data generated for individual orbital passes of Lunar Orbiter Missions II, III, and V. Area landmark points and potential lunar landing points were included.

This control data consisting of 177 points is based on a LOSAT Analytical Triangulation solution which employed the same photography used in the 1967 solution with refined Photo Support Data, dated October 1968. Its usage is preferred over the 1967 system.

3. Site II-2 Area (1968) System (Site East Two System).

The Site II-2 Area (1968) System was produced by TOPOCOM in December 1968 as an amalgamation of overlapping control systems which had been generated to enable evaluation of consistency of Photo Support Data. The LORMS program was used to combine the following systems into a single system:

Site II-2 (1968)
Site III-1 (1968) (Section 3.3.1.14)
Site V-11 (1968) (Section 3.3.1.20)

3.3.1.10 SITE II-6 (1967) AND (1969) SYSTEMS

1. Site II-6 (1967) System.

The Site II-6 (1967) Control System was produced by TOPOCOM in September 1967 to support site mapping. It is composed of some 1400 points and is located at 1°7'N and 24°0'E with coverage as indicated in Control Index No. I(4).

The LOSAT analytical triangulation program was used to develop site coordinates in two overlapping photo strips composed of medium resolution Lunar Orbiter Mission II frames 76-83 and 84-91. Selenographic coordinates from these two solutions which are based on individual strip Photo Support Data are available as control subsystems II-6a (1967) and II-6b (1967). A combination of the II-6a and II-6b systems was effected through the LORMS program to produce Site II-6 system control values.

The II-6 System was produced with an evaluated horizontal accuracy (90% probability) of 88 meters and vertical accuracy (90% probability) of 262 meters relative to the datum defined by the preliminary Photo Support Data. Points related to the DOD Selenodetic System (1966) were included in the LOSAT computation. However, the limited weight given these points did not allow them to significantly affect the solution.

2. Site II-6 (1969) System.

The Site II-6 (1969) System was produced by TOPOCOM in January 1969 to provide basic information bearing on the consistency of Photo Support Data generated for individual orbital passes of Lunar Orbiter Missions II, III and V. Area landmark points and potential lunar landing points were included.

This control data consisting of approximately 130 points is based on a LOSAT analytical triangulation solution which employed the same photography used in the 1967 solution with refined Photo Support Data, dated October 1968. As in the earlier solution, coordinate values are available in sub-systems II-6a (1969) and II-6b (1969). Its usage is preferred over the 1967 system.

3. Site II-6 Area (1969) System (Site East One System).

The Site II-6 Area (1969) System was produced by TOPOCOM in January 1969 as an amalgamation of overlapping control systems which had been generated to enable evaluation of consistency of Photo Support Data. The LORMS program was used to combine the II-6 (1969) system with the V-16 (1968) system.

3.3.1.11 SITE II-8 (1967) (1969) (1971) SYSTEMS

1. Site II-8 (1967) System.

The Site II-8 (1967) System was produced by ACIC in July 1967 to support lunar site mapping. It is composed of some 775 points and is located at 0°N and 1°W as indicated on Control Index No. I(4). The Satellite Strip Control Extension Program (SSCE), a forerunner of LOSAT, was used to develop analytical strip solutions which are available as control subsystems II-8a (1967), II-8b (1967) and II-8c (1967). The three orbital photographic strips were developed from Lunar Orbiter Mission II medium resolution frames 113-136 and preliminary Photo Support Data dated February 1967.

They were adjusted to the absolute position reflected by strip 8b Photo Support Data and had an evaluated accuracy of 28 meters horizontally and 65 meters vertically (90% probability) with respect to the strip 8b defined datum. However, systematic (parabolic) distortion was evident in these strip solutions and the elevation data is of value only for local topographic differences reflected.

2. Site II-8 (1969) Systems.

The II-8 (1969) Systems were produced by ACIC in February 1969 to provide basic information bearing on the consistency of Photo Support Data generated for individual orbital passes of Lunar Orbiter Missions II, III, and V. Area landmark points and potential lunar landing points were included.

The control data consisting of approximately 133 points was based on LOSAT analytical triangulation solutions which employed the same photography used in the 1967 solutions and refined Photo Support Data dated October 1968. Coordinate values are only available in terms of the sub-systems II-8a (1969), II-8b (1969), II-8c (1969) derived from the individual LOSAT solutions. Following are the II-8 (1969) sub-systems evaluated horizontal and vertical accuracy (90% probability), stated with respect to the datum defined by the 1968 Photo Support Data.

Sub-system	Horizontal	Vertical
II-8a (1969)	40 meters	106 meters
II-8b (1969)	40 meters	128 meters
II-8c (1969)	60 meters	136 meters

3. Site II-8 Area (1969) System.

The Site II-8 Area (1969) System was produced by ACIC in February 1969 as an amalgamation of overlapping control systems which had been generated to enable evaluation of consistency of Photo Support Data. The II-8 Area (1969) System control was formed by an adjustment of II-8 (1969), III-7 (1969), and V-27 (1969) sub-systems into a single system. The datum of the single system is reflective of the combination of III-7a, III-7b, V-27a and V-27b Photo Support Data. Control points used to establish the adjusted system have an evaluated horizontal accuracy (90% probability) of 25 meters and vertical accuracy (90% probability) of 50 meters. Coordinate values are available in terms of sub-systems II-8a (1969), II-8b (1969) and II-8c (1969) as produced from the individual LOSAT solutions.

4. Site II-8 Area (1971) System.

The Site II-8 (1971) Systems were produced by ACIC in July 1971 as a byproduct of the performance of a Control Extension Test. Control data consisting of approximately 117 points is based on a LOSAT computation which employed the same photography used in earlier solutions and Photo Support Data dated September 1969. Coordinates are available only in terms of sub-systems II-8a (1971), II-8b (1971) and II-8c (1971) produced from the individual LOSAT solutions. Evaluations of the II-8 (1971) sub-systems produced with the 1969 Photo Support Data are comparable to those of the II-8 (1969) sub-systems. Use of the II-8 (1971) sub-systems is preferred over previous II-8 systems due to incorporation of the 1969 Photo Support Data and refined computation.

3.3.1.12 SITE II-11 (1967) SYSTEM

The Site II-11 (1967) Control System was produced by TOPOCOM in September 1967 to support site mapping. It is composed of 663 points and is located at 0°7'S and 19°45'W with coverage as indicated in Control Index No. I(4).

The LOSAT analytical triangulation program was used to develop site coordinates in two overlapping photo strips composed of medium resolution Lunar Orbiter Mission II frames 163-167 and 170-178. Selenographic coordinates from these two solutions which are based on individual strip Photo Support Data, are available as control sub-systems II-11a (1967) and II-11b (1967). A combination of the II-11a and II-11b systems was effected through the LORMS program to produce Site II-11 system control values.

The II-11 system was produced with an evaluated horizontal accuracy (90% probability) of 62 meters and vertical accuracy (90% probability) of 130-180 meters relative to the datum defined by the preliminary Photo Support Data. Points related to the DOD Selenodetic System (1966) were included in the LOSAT computation. However, the limited weight given these points did not allow them to significantly affect the solution.

3.3.1.13 SITE II-13 (1967) AND (1968) SYSTEMS

1. Site II-13 (1967) System.

The Site II-13 (1967) Control System was produced by TOPOCOM in July 1967 to support site mapping. It is composed of 688 points and is located at 1°45'N and 41°30'W with coverage as indicated in Control Index No. I(4).

The LOSAT analytical triangulation program was used to develop site coordinates in two overlapping photo strips composed of medium resolution Lunar Orbiter Mission II frames 197-204 and 205-212. Selenographic coordinates from these two solutions which are based on individual strip Photo Support Data are available as control sub-systems II-13a (1967) and II-13b (1967). A combination of II-13a and II-13b systems was effected through the LORMS program to produce Site II-13 system control values.

The II-13 System was produced with an evaluated horizontal accuracy (90% probability) of 85 meters and vertical accuracy (90% probability) of 190-225 meters relative to the datum defined by the preliminary Photo Support Data. Points related to the DOD Selenodetic System (1966) were included in the LOSAT computation. However, the limited weight given these points did not allow them to significantly affect the solution.

2. Site II-13 (1968) System.

The Site II-13 (1968) System was produced by TOPOCOM in December 1968 to provide basic information bearing on the consistency of Photo Support Data generated for individual orbital passes of Lunar Orbiter Missions II, III, and V. Area landmark points and potential lunar landing points were included.

This control data consisting of approximately 150 points is based on a LOSAT analytical triangulation solution which employed the same photography used in the 1967 solution with refined Photo Support Data, dated October 1968. As in the earlier solution, coordinate values are available in sub-systems II-13a (1968) and II-13b (1968). Its usage is preferred over the 1967 system.

3. Site II-13 Area (1968) System (Site West One System).

The Site II-13 Area (1968) System was produced by TOPOCOM in December 1968 as an amalgamation of overlapping control systems which had been generated to enable evaluation of consistency of Photo Support Data. The LORMS program was used to combine the II-13 (1968) system with the III-10 (1968) system which is described in Section 3.3.1.17.

3.3.1.14 SITE III-1 (1968) SYSTEM

The Site III-1 (1968) Control System was produced by TOPOCOM in December 1968 to provide basic information bearing on the consistency of Photo Support Data generated for individual orbital passes of Lunar Orbiter Missions II, III, and V. Area landmark points and potential lunar landing points were included. It is composed of 153 points and is located at 2°45'N and 35°15'E with coverage as indicated in Control Index No. I(5).

The control data is based on a LOSAT analytical triangulation solution which employed medium resolution lunar Orbiter Mission III exposures 5, 9, 11, 13, 15, 17, 19 and Photo Support Data dated October 1968. The accuracy of this system is unevaluated.

3.3.1.15 SITE III-7 (1969) (1971) SYSTEMS

1. Site III-7 (1969) Systems.

The Site III-7 (1969) control systems were produced by ACIC in February 1969 to provide basic information bearing on the consistency of Photo Support Data generated for individual orbital passes of Lunar Orbiter Missions II, III and V. Area landmark points and potential lunar landing points were included. The III-7 Systems are composed of 122 points and are located at 0°N and 1°W with coverage as indicated in Control Index No. I(5).

Coordinate values are only available in terms of sub-systems III-7a (1969) and III-7b (1969) produced from individual LOSAT solutions. Lunar Orbiter Mission III medium resolution frames 86-101 and Photo Support Data dated October 1968 were used in developing these systems. They have the following evaluated horizontal and vertical accuracy (90% probability).

Sub-system	Horizontal	Vertical
III-7a	56 meters	54 meters
III-7b	24 meters	43 meters

2. Site III-7 (1971) Systems.

The Site III-7 (1971) Systems were produced by ACIC in July 1971 as a byproduct of the performance of a Control Extension Test. Control data consisting of approximately 110 points was based on a LOSAT computation which employed the same photography used in earlier solutions and Photo Support Data dated September 1969. Coordinates are available only in terms of sub-systems III-7a and III-7b produced from the individual LOSAT solutions. Relative accuracies achieved with the III-7 (1971) sub-systems are comparable to those of the III-7 (1969) sub-systems.

3.3.1.16 SITE III-9 (1967) AND (1969) SYSTEMS

1. Site III-9 (1967) System.

The Site III-9 (1967) Control System was produced by TOPOCOM in November 1967 to support site mapping. It is composed of some 1023 points and is located at 3°7'S and 22°45'W with coverage as indicated in Control Index No. I(5).

The LOSAT analytical triangulation program was used to develop site coordinates in two overlapping photo strips composed of medium resolution Lunar Orbiter Mission III frames 145-152 and 153-160. Selenographic coordinates from these two solutions which are based on individual strip Photo Support Data are available as control sub-systems III-9b (1967) and III-9c (1967). A combination of the III-9b and III-9c systems was effected through the LORMS program to produce Site III-9 system control values.

The III-9 system was produced with an evaluated horizontal accuracy (90% probability) of 58 meters and vertical accuracy (90% probability) of 100-300 meters relative to the datum defined by the preliminary Photo Support Data dated April 1967.

2. Site III-9 (1969) System.

Site III-9 (1969) System was produced by TOPOCOM in September 1969 to support the Mission Apollo 12 landing. It consists of approximately 400 points. Landmark points, Apollo 12 landing ellipse center, and the Surveyor III spacecraft image were included in the triangulation. The III-9 (1969) System was based on LORMS analytical triangulation solution which employed the same photography as in the 1967 systems and Photo Support Data dated October 1968.

3.3.1.17 SITE III-10 (1968) SYSTEM

The Site III-10 (1968) control system was produced by TOPOCOM in December 1968 to provide basic information bearing on the consistency of Photo Support Data generated for individual orbital passes of Lunar Orbiter Missions II, III and V. Area landmark points and potential lunar landing points were included. It is composed of 164 points and is located at 1°45'N and 41°45'W with coverage as indicated in Control Index No. I(5).

The control data is based on a LOSAT analytical triangulation solution which employed medium resolution Lunar Orbiter Mission III exposures 163-170 and Photo Support Data dated October 1968. The accuracy of this System is unevaluated.

3.3.1.18 SITE III-11 (1967) AND (1968) SYSTEMS

1. The Site III-11 (1967) Control System was produced by TOPOCOM in November 1967 to support site mapping. It is composed of 1277 points and is located at 3°15'S and 36°30'W, with coverage as indicated in Control Index No. I(5).

The LOSAT analytical triangulation program was used to develop site control points with Lunar Orbiter Mission III medium resolution exposures 173-180 and preliminary Photo Support Data. The III-11 system was produced with an evaluated horizontal accuracy (90% probability) of 72 meters and vertical accuracy (90% probability) of 100-300 meters relative to the datum defined by the preliminary Photo Support Data dated April 1967.

2. Site III-11 (1968) System.

The Site III-11 (1968) system was produced by TOPOCOM in December 1968 to provide basic information bearing on the consistency of Photo Support Data generated for individual orbital passes of Lunar Orbiter Missions II, III and V. Area landmark points and potential lunar landing points were included.

This control data consisting of 160 points is based on a LOSAT analytical triangulation solution which employed the same photography used in the 1967 solution with refined Photo Support Data, dated October 1968. Its usage is preferred over the 1967 system.

3. Site III-11 Area (1968) System (Site West Two System).

The Site III-11 Area (1968) System was produced by TOPOCOM in December 1968 as an amalgamation of overlapping control systems which had been generated to enable evaluation of consistency of Photo Support Data. The LORMS program was used to combine the III-11 (1968) with V-42 (1968) system which is described in Section 3.3.1.24.

3.3.1.19 SITE III-12 (1967) AND (1968) SYSTEMS

1. Site III-P-12 (1967) System.

The Site III-P-12 (1967) Control System was produced by ACIC in December 1967 to support site mapping and to evaluate triangulation usage of oblique Lunar Orbiter photography. The system is composed of approximately 285 points and is located at 2°30'S latitude and 43°30'W longitude with coverage as indicated in Control Index No. I(5).

The Satellite Strip Control Extension Program (SSCE) was used to develop site control points. This analytical photogrammetric program, a forerunner of LOSAT, also employs orbital constraints. Preliminary Lunar Orbiter Mission III Photo Support Data produced by Jet Propulsion Laboratory in November 1967 and medium resolution photography of photo strips 12a, 12b1, 12b2, and 12c were used in computing this solution. The four photographic strips had local roll angles of from 4° to 28°.

Although good relativity was achieved within each SSCE strip solution, lunar surface points derived from different strips exhibited biases in the order of 2 km. Horizontal and vertical adjustments of the four strips were performed to the surface defined by strip 12a to produce a single site control system. The vertical adjustments did not adequately compensate for interstrip differences and elevations were not produced or published in this system. Horizontal adjustment resulted in a single system having an accuracy of approximately 130 meters (90% probability) relative to the datum defined by strip 12a Photo Support Data.

2. Site III-P-12 (1968) System.

The Site III-P-12 (1968) System was produced by ACIC in March 1968 in response to the failure of the adjusted vertical solution in the 1967 system.

This system used the LOBAT program to block the four Lunar Orbiter III strip solutions together achieving a 20 meter horizontal and 30 meter vertical (90% accuracy) relative to the datum defined by the November 1967 edition of Lunar Orbiter Photo Support Data.

3.3.1.20 SITE V-11 (1968) SYSTEM

The Site V-11 (1968) Control System was produced by TOPOCOM in December 1968 to provide basic information bearing on the consistency of Photo Support Data generated for individual orbital passes of Lunar Orbiter Missions II, III, and V. It was composed of approximately 170 points and is located at 2°45'N and 34°30'E with coverage as indicated in Control Index No. I(5).

The LOSAT analytical triangulation program was used to develop site coordinates in two overlapping photo strips composed of medium resolution Lunar Orbiter Mission V frames 55-58 and 59-62. Selenographic coordinates from these two solutions which are based on individual strip Photo Support Data dated October 1968 are available as control sub-systems V-11a (1968) and V-11b (1968). A combination of the V-11a and V-11b systems was effected through the LORMS program to produce Site V-11 system control values. The accuracy of this system is unevaluated.

3.3.1.21 SITE V-16 (1969) SYSTEM

The Site V-16 (1969) Control System was produced by TOPOCOM in January 1969 to provide basic information bearing on the consistency of Photo Support Data generated for individual orbital passes of Lunar Orbiter Missions II, III and V. It was composed of approximately 120 points and is located at 1°15'N and 24°0'E with coverage as indicated in Control Index No. I(5).

The LOSAT analytical triangulation program was used to develop site coordinates in two overlapping photo strips composed of medium resolution Lunar Orbiter Mission V frames 71-74 and 75-78. Selenographic coordinates from these two solutions which are based on individual strip Photo Support Data dated October 1968 are available as control sub-systems V-16a (1968) and V-16b (1968). A combination of V-16a and V-16b systems was effected through the LORMS program to produce Site V-16 system control values. The accuracy of this system is unevaluated.

3.3.1.22 SITE V-27 (1969) (1971) SYSTEMS

1. Site V-27 (1969) Systems.

The Site V-27 (1969) Control Systems were produced by ACIC in February 1969 to provide basic information bearing on the consistency of Photo Support Data generated for individual orbital passes of Lunar Orbiter Missions II, III, and V. The V-27 systems are composed of 115 points and are located at 0°0'N and 1°0'W with coverage as indicated on Control Index No. I(5). Area landmark points and potential lunar landing points were included.

The LOSAT analytical triangulation program was used to develop site control points with Lunar Orbiter Mission V medium resolution frames 108-111 and 112-115 and Photo Support Data dated October 1968. Coordinate values are available in terms of sub-systems V-27a and V-27b. They were produced relative to the datum defined by the 1968 Photo Support Data with an evaluated horizontal and vertical accuracy (90% probability) as follows:

Sub-system	Horizontal	Vertical
V-27a	54 meters	136 meters
V-27b	73 meters	123 meters

2. Site V-27 (1971) Systems.

The Site V-27 (1971) Control Systems were produced by ACIC in July 1971 as a byproduct of the performance of a Control Extension Test. Control data consisting of approximately 90 points is based on LOSAT computations which employed the same photography used in the earlier solutions and Photo Support Data dated September 1969. Coordinates are available only in terms of sub-systems V-27a and V-27b as produced from the individual LOSAT solutions. Point accuracy factors did not vary significantly from 1969 system. The 1969 and 1971 systems have comparable relativity but the datum of the latter is preferred.

3.3.1.23 SITE V 31 (1971) SYSTEM

The Site V-31 (1971) Control System was produced by ACIC in July 1971 as a byproduct of a Control Extension Test. The system consists of some 66 points and is located 48°N and 2°W with coverage as indicated on Control Index No. I(5).

The LOSAT analytical triangulation program was used to perform this triangulation with Orbiter V medium resolution exposures 129-132 and Photo Support Data dated September 1969. The V-31 (1971) System has an elevated horizontal accuracy (90% probability) of 295 meters and vertical accuracy (90% probability) of 923 meters relative to the datum defined by the Photo Support Data.

3.3.1.24 SITE V-42 (1968) SYSTEM

The Site V-42 (1968) control system was produced by TOPOCOM in December 1968 to provide basic information bearing on the consistency of Photo Support Data generated for individual orbital passes of Lunar Orbiter Missions II, III and V. It was composed of approximately 130 points and is located at 3°0'S and 36°0'W with coverage as indicated on Control Index No. I(5).

The LOSAT analytical triangulation program was used to develop site coordinates in two overlapping photo strips composed of medium resolution Lunar Orbiter Mission V frames 169-172 and 173-176. Selenographic coordinates from these two solutions which are based on individual strip Photo Support Data dated October 1968 are available as control sub-systems V-42a (1968) and V-42b (1968). A combination of the V-42a and V-42b systems was effected through the LORMS program to produce V-42 system control values. The accuracy of this system is unevaluated.

3.3.1.25 ALPHONSUS (1971) SYSTEM

The Alphonsus (1971) Control System was produced by TOPOCOM in September 1971 to support lunar site mapping. It is composed of some 1700 points and is located at 13°45'S and 4°0'W with coverage as indicated on Control Index No. I(5).

The LOSAT analytical triangulation program was used to develop control points with Lunar Orbiter V medium resolution frames 116-119 and Photo Support Data dated October 1968. Alphonsus (1971) System has an evaluated horizontal accuracy (90% probability) of 250 meters and vertical accuracy (90% probability) of 371-1015 meters relative to the datum defined by the 1968 Photo Support Data.

3.3.1.26 ARISTARCHUS (1969) SYSTEM

The Aristarchus (1969) Control System was produced by ACIC in October 1969 to support lunar site mapping. It is composed of some 1400 points and is located at 24°N and 47°W with coverage as indicated on Control Index No. I(5).

The LOSAT analytical triangulation program was used to develop site control points with Lunar Orbiter V medium resolution exposures 194-201 and Photo Support Data dated September 1969. The Aristarchus (1969) system was produced with an evaluated horizontal accuracy (90% probability) of 20-298 meters and a vertical accuracy (90% probability) of 98-542 meters relative to the datum defined by the 1969 Photo Support Data.

3.3.1.27 CENSORINUS (1968) SYSTEM

The Censorinus (1968) System was produced by TOPOCOM in November 1968 to provide control data for the Censorinus site. It is composed of approximately 41 points and is located at 0°N with coverage as indicated on Control Index I(5).

The MUSAT analytical triangulation program was used to develop site coordinates, with high resolution Lunar Orbiter Mission IV frames 72 and 73 and medium resolution Mission V frame 63. Twenty-one points were measured on frame V-63 and tied to the Orbiter IV frames. Twenty additional points outside the area of the V-63 frame were measured on frames 72 and 73 to increase the geometric strength of the solution. Selenographic coordinates from this block solution were based on post-mission Photo Support Data dated October 1968. Approximately 200 additional point coordinates were produced in the site area. These points were not included in the triangulation network. The Censorinus (1968) System was produced with an evaluated horizontal accuracy (90% probability) of ± 144 meters and vertical accuracy (90% probability) of ± 262 meters relative to the datum defined by the October 1968 Photo Support Data.

3.3.1.28 COPERNICUS (1969) SYSTEM

The Copernicus (1969) Control System was produced by TOPOCOM in September 1969 to support lunar site mapping. Area landmarks, profile points and potential landing points were included. It is composed of approximately 1800 points and is located at 10°15'N and 20°40'W with coverage as indicated on Control Index No. I(5).

The LOSAT analytical triangulation program was used to develop control points with Lunar Orbiter Mission V medium resolution exposures 150-157 and Photo Support Data dated October 1968. The Copernicus control system was produced with an evaluated horizontal accuracy (90% probability) of 88 meters and vertical accuracy (90% probability) of 102-585 meters relative to the datum defined by the Photo Support Data published October 1968.

3.3.1.29 FRA MAURO (JUNE 1969) AND (OCTOBER 1969) SYSTEMS

1. Fra Mauro (June 1969) System.

The Fra Mauro (June 1969) System was produced by ACIC in June 1969 to support lunar site mapping. It is composed of some 1225 points and is located at 4°S and 17°W with coverage as indicated in Control Index No. I(5).

The LOSAT analytical triangulation program was used to develop site control points with Lunar Orbiter Mission III medium resolution frames 132-135 and Photo Support Data dated October 1968. The Fra Mauro system was produced with an evaluated horizontal accuracy (90% probability) of 17-90 meters and a vertical accuracy (90% probability) of 32-86 meters relative to the datum defined by the Photo Support Data.

2. Fra Mauro (October 1969) System.

The Fra Mauro (October 1969) System was produced by ACIC in October 1969 by LOSAT recomputation using Photo Support Data dated September 1969. The October 1968 Photo Support data used in the earlier system was found to be erroneous and this solution produced control data with respect to corrected horizontal and vertical datums. Point accuracy factors did not vary significantly from the June 1969 solution.

3.3.1.30 GASSENDI (1969) SYSTEM

The Gassendi (1969) Control System was produced by TOPOCOM in May 1969 to support lunar site mapping. It is composed of approximately 1370 points and is located at 16°45'S and 40°25'W with coverage as indicated [illegible] Index No. I(5).

The LOSAT analytical triangulation program was used to develop site control points with Lunar Orbiter V medium resolution exposures 177-180 and Photo Support Data dated October 1968. The Gassendi System was produced with an evaluated horizontal accuracy (90% probability) of [illegible] meters and vertical accuracy (90% probability) of 138-263 meters relative to the datum defined by the 1968 Photo Support Data.

3.3.1.31 HIPPARCHUS (1969) SYSTEM

The Hipparchus (1969) Control System was produced by TOPOCOM in May 1969 to support lunar site mapping. It is composed of approximately 780 points and is located at 4°45'S and 4°0'E with coverage as indicated on Control Index No. I(5).

The LOSAT and LOBAT analytical triangulation programs were used to develop site control points with Lunar Orbiter medium resolution frames 98-101 (Orbiter V-24) and 108-111 (Orbiter III-17) and Photo Support Data dated October 1968. A combination of III-17 and V-24 exposures was effected through the LOBAT Program to produce the Hipparchus System.

The Hipparchus (1969) System was produced with an evaluated horizontal accuracy (90% probability) of 82 meters and vertical accuracy (90% probability) of 164 to 441 meters relative to the datum defined by the 1968 Photo Support Data.

3.3.1.32 MARIUS F (1969) SYSTEM

The Marius F (1969) Control System was produced by TOPOCOM in July 1970, to support lunar site mapping. Potential area landing points were included. It is composed of some 1200 points and is located at 13°30'N and 55°25'W with coverage as indicated on Control Index No. I(5).

The LOSAT analytical triangulation program was used to develop control points with Lunar Orbiter V medium resolution frames 210-216 and Photo Support Data dated October 1968. The Marius F (1969) System was produced with an evaluated horizontal accuracy (90% probability) of 103 meters and vertical accuracy (90% probability) of 126-609 meters relative to the datum defined by the 1968 Photo Support Data.

3.3.1.33 MOSTING C (1969) SYSTEM

The Mosting C (1969) System was produced by ACIC in June 1969 to support lunar site mapping. It is composed of some 483 points and is located at 2°S and 8'W with coverage as indicated on Control Index No. I(5).

The LOSAT analytical triangulation program was used to develop site control points with Lunar Orbiter Mission III medium resolution frames 112-115 and Photo Support Data dated October 1968. The Mosting C System was produced with an evaluated horizontal accuracy (90% probability) of 17-188 meters and vertical accuracy (90% probability) of 58-121 meters relative to the datum referenced by the October 1968 Photo Support Data.

3.3.1.34 PRINZ (1969) SYSTEM

The Prinz (1969) Control System was produced by TOPOCOM in October 1969 to support lunar site mapping. It is composed of some 1350 points and is located at 26°54'N and 43°35'W with coverage as indicated on Control Index No. I(5).

The LOSAT analytical triangulation program was used to develop control points with Lunar Orbiter V medium resolution exposures 186-193 and Photo Support Data dated October 1968. Evaluated accuracy of the Prinz (1969) System relative to the datum defined by the 1968 Photo Support Data is 126 meters horizontally and 130-195 meters vertically (90% probability).

3.3.1.35 RIMA HADLEY (1970) SYSTEM

The Rima Hadley (1970) Control System was produced by TOPOCOM in January 1970 to support lunar site mapping. Area landmarks, potential landing points, and profile points were included. It is composed of approximately 1150 points and is located at 22°30'N and 3°23'E with coverage as indicated on Control Index No. I(5).

The LOSAT analytical triangulation program was used to develop site control points with Lunar Orbiter V medium resolution exposures 104-107 and Photo Support Data dated September 1969. Use of the 1969 Photo Support Data for this site was necessitated by exposure time inconsistencies evidenced in the 1968 Photo Support Data.

The Rima Hadley (1970) System was produced with an evaluated horizontal accuracy (90% probability) of 86 meters and vertical accuracy (90% probability) of 142-250 meters relative to the datum established by the 1969 Photo Support Data.

3.3.1.36 RIMA HYGINUS (1969) SYSTEM

The Rima Hyginus (1969) Control System was produced by TOPOCOM in May 1969 to support lunar site mapping. It is composed of some 1270 points and is located at 8°0'N and 5°45'E with coverage as indicated on Control Index No. I(5).

The LOSAT analytical triangulation program was used to develop site control points with Orbiter V medium resolution exposures 94-97 and Photo Support Data dated October 1968. The Rima Hyginus 1969 Control System was produced with an evaluated horizontal accuracy (90% probability) of 177 meters and vertical accuracy (90% probability) of 227-503 meters relative to the datum defined by 1968 Photo Support Data.

3.3.1.37 RIMAE LITTROW (1969) AND (1970) SYSTEMS

1. Rimae Littrow (1969) System.

The Rimae Littrow (1969) Control System was produced by TOPOCOM in May 1969 to support site mapping. It is comprised of approximately 900 points and is located at 21°55'N and 29°19'E with coverage as indicated on Control Index No. I(5).

The LOSAT analytical triangulation program was used to develop site control points with Orbiter V medium resolution exposures 66-69 and Photo Support Data dated October 1968. The Rimae Littrow (1969) System was produced with a horizontal accuracy (90% probability) of 164 meters and vertical accuracy (90% probability) of 392 to 676 meters as referenced to the datum established by the October 1968 Photo Support Data.

2. Rimae Littrow (1970) System.

Site Littrow, Apollo 14 Landmark Triangulation System, was produced by TOPOCOM, May 1970, in support of the Apollo 14 Mission. Eighteen landmark landing points and six landing ellipse centers were included in the triangulation.

This control system incorporated the same points, Photo Support Data, and exposures that were used in the 1969 system.

3.3.1.38 RIMA BODE II (1969) (1971) SYSTEMS

1. Rima Bode II (1969) System.

The Rima Bode II (1969) System was produced by ACIC in September 1969 to support lunar site mapping. It is composed of some 1230 points and is located at 12°N and 4°W with coverage as indicated on Control Index No. I(5).

The LOSAT analytical triangulation program was used to develop site control points with Lunar Orbiter Mission V medium resolution frames 120-123 and Photo Support Data dated October 1968. The Rima Bode II (1969) System was produced with an evaluated horizontal accuracy (90% probability) of 21-351 meters and vertical accuracy of 145-420 meters (90% probability) relative to the datum defined by Photo Support Data.

2. Rima Bode II (1971) System.

The Rima Bode II (1971) System was produced by ACIC in July 1971 as a byproduct of the performance of a Control Extension Test. Control data consisting of approximately 80 points is based on a LOSAT computation which employed the same photography used in the earlier solution and Photo Support Data dated September 1969. Point accuracy factors did not vary significantly from the 1969 system. The 1971 system is preferred.

3.3.1.39 TYCHO (1971) SYSTEM

The Tycho (1971) Control System was produced by TOPOCOM in 1971 to support lunar site mapping. It is composed of some 840 points and is located at 41°26'S and 11°29'W with coverage as indicated on Control Index No. I(5).

The LOSAT analytical triangulation program was used to develop site control points with Lunar Orbiter Mission V frames 125-128 and Photo Support Data dated October 1968. The Tycho (1971) System was produced with an evaluated horizontal accuracy (90% probability) of 4[illegible]3 meters and vertical accuracy (90% probability) of 696 to 1885 meters relative to the datum defined by the 1968 Photo Support Data.

3.3.2.1 DESCARTE (1971) SYSTEM

The Descarte (1971) Control System was produced by TOPOCOM in 1971 to support pre-mission study and mapping of the Apollo 16 landing site. It is composed of some 250 points and is located at 9°00'S and 15°30'E with coverage as indicated in Control Index I(4).

The LOSAT analytical triangulation was used to develop site coordinates with Apollo 14 80mm focal length Hassleblad frames 9780-9786, Apollo 14 Photo Support Data and Landmark Tracking Points (Section 3.2.2). As the triangulation solution was primarily constrained to the Landmark Tracking Values, the datum of the Descarte System is closely related to the Landmark Tracking System. Points common to the Apollo 12 (TOPOCOM 1971) System (Section 3.2.3.3) are carried in this triangulation.

The Descarte System was produced with an evaluated horizontal accuracy of 47 meters (90% probability) and a vertical accuracy of 105-181 meters (90% probability) with respect to the established datum.

More detailed Descarte System information is given in reference 3.4.51.

3.3.2.2 TAURUS LITTROW (1972) SYSTEM

The Taurus Littrow (1972) Control System was produced by DMAAC in April 1972 to support pre-mission study and mapping of the Apollo 17 landing site. It is composed of some 200 points and is located at 20°30'N and 31°00'E with coverage as indicated in Control Index No. I(4).

The LOSAT analytical triangulation program was used to develop site coordinates with Apollo 15 mapping camera frames 966, 968, 970, 972, 974, camera orientation data from companion stellar exposures and orbital revolution 27 Photo Support Data. A greater density of control points is provided in the immediate landing site area.

The Taurus Littrow System was produced with an evaluated horizontal accuracy of 31 meters (90% probability) and a vertical accuracy of 56 meters (90% probability) with respect to the datum established from Apollo 15 Orbital Revolution 27 Photo Support Data.

This System and the overlapping Rimae Littrow (1969) and (1970) Systems (Section 3.3.1.37) are obsoleted by the Apollo 15 and Apollo 17 Regional Control Systems (Section 3.2.3.5 and 3.2.3.6).

More detailed information is given in reference 3.4.52.

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3.4.25 Department of Defense Selenodetic Control System 1966; Army Map Service; 1967

3.4.26 Lunar Landmark Locations-Apollo 8, 10, 11 and 12 Missions; NASA Technical Note TN D-6082; November 1970

3.4.27 The Analytical Aero Triangulation of the Apollo 10 Hasselblad Photography; DBA Final Report for NASA Manned Spacecraft Center; November 1970

3.4.28 Apollo Mission 12 Triangulation; Technical Report, NASA Contract No. W-13, 208, ACIC; July 1971

3.4.29 Development of Apollo 12 Triangulation; NASA Defense Purchase Request No. W-13, 283, TOPOCOM; July 1971

3.4.30 Production Summary of the Triangulation and Compilation of Missions I, II and III Lunar Landing Site Areas; Report for NASA, Army Map Service; May 1968

3.4.31 Triangulation Comparison-Summary of Results; Army Map Service; January 1969

3.4.32 Photogrammetric Triangulation with Lunar Orbiter III Photography (Site III-P-12); Technical Report, ACIC.

3.4.33 Photogrammetric Triangulation, Lunar Orbiter III-Scientific Site S-18 (Mosting C); Technical Report, ACIC; July 1969

3.4.34 Photogrammetric Triangulation, Lunar Orbiter III, Scientific Site S-23 (Fra Mauro); Technical Report, ACIC; undated

3.4.35 Lunar Site V-31 Triangulation; Technical Report, NASA Contract No. W-13, 208, ACIC; September 1971

3.4.36 Lunar Exploration Site V-12, Censorinus; Project History, NASA Contract No. W-12, 375, TOPOCOM; August 1969

3.4.37 Mapping of Scientific Site V-14 Rimae Littrow; Project History NASA Contract No. W-12, 375, TOPOCOM; August 1970

3.4.38 Lunar Exploration Site V-23.1 Rima Hyginus; Project History NASA Contract No. W-12, 375, TOPOCOM; August 1970

3.4.39 Mapping of Scientific Site V-24 Hipparchus; Project History NASA Contract No. W-12, 375, TOPOCOM; December 1970

3.4.40 Mapping of Scientific Site V-26.1 Rima Hadley; Project History NASA Contract W-12, 375, TOPOCOM; November 1970

3.4.41 Photogrammetric Triangulation, Lunar Orbiter V Scientific Site V-29 (Rima Bode II); Technical Report, ACIC

3.4.42 Lunar Exploration Site V-30 Tycho; Project History, NASA Contract W-12, 375, TOPOCOM; July 1971

3.4.43 Mapping of Scientific Site V-37 Copernicus; Project History NASA Contract W-12, 375, TOPOCOM; December 1970

3.4.44 Mapping of Scientific Site V-46 Prinz; Project History, NASA Contract W-12, 375, TOPOCOM; December 1970

3.4.45 Photogrammetric Triangulation Lunar Orbiter V Scientific Site S-48 (Aristarchus); Technical Report, ACIC; September 1969

3.4.46 Mapping of Scientific Site V-51 Marius Hills; Project History NASA Contract W-12, 375, TOPOCOM; July 1970

3.4.47 Photogrammetric Triangulation with Orbiter I Photography; Summary Report, ACIC

3.4.48 Evaluation of Photo Support Data - Apollo Site II P-8 Area, Technical Report, ACIC; February 1969

3.4.49 Photogrammetric Triangulation with Lunar Orbiter II Photography; Technical Report, ACIC; August 1967

3.4.50 A Positional Reference System of Lunar Features Determined From Lunar Orbiter Photography; Ruffin; ACIC; May 1969

3.4.51 Mapping of Apollo 16 Landing Site DESCARTES, Project History, TOPOCOM, November 1971

3.4.52 Apollo 15 Taurus Littrow Triangulation Report, ACIC; April 1972

3.4.53 Apollo 15 Initial Metric System Evaluation Report, ACIC; March 1972

3.4.54 Development of the Apollo 15 Control Network, DMAAC; August 1973

3.4.55 Evaluation of the Apollo 16 Mapping Camera Subsystem, DMATC; May 1973

3.4.56 Relationship of Spacecraft and Earthbased Selenodetic Systems, Schimerman, Cannell and Meyer, DMAAC; August 1973

3.4.57 Apollo 17 Initial Metric System Evaluation Report, DMAAC; April 1974

3.4.58 Development of the Apollo Mission 17 Control Network, DMAAC; January 1975

3.4.59 Location of Lunakhod 2 From Laser Ranging Observations, Mulholland, Shelus and Silverberg, Depart. of Astronomy and McDonald Observatory, University of Texas; May 1973

3.4.60 The Lunar Laser Ranging Experiment, Bendec, Currie, Eckhardt, Faller, Kaula, Mulholland, Plotkin, Poultney, Silverberg, Wilkinson, Williams, Alley, Volume 182, SCIENCE; October 1973

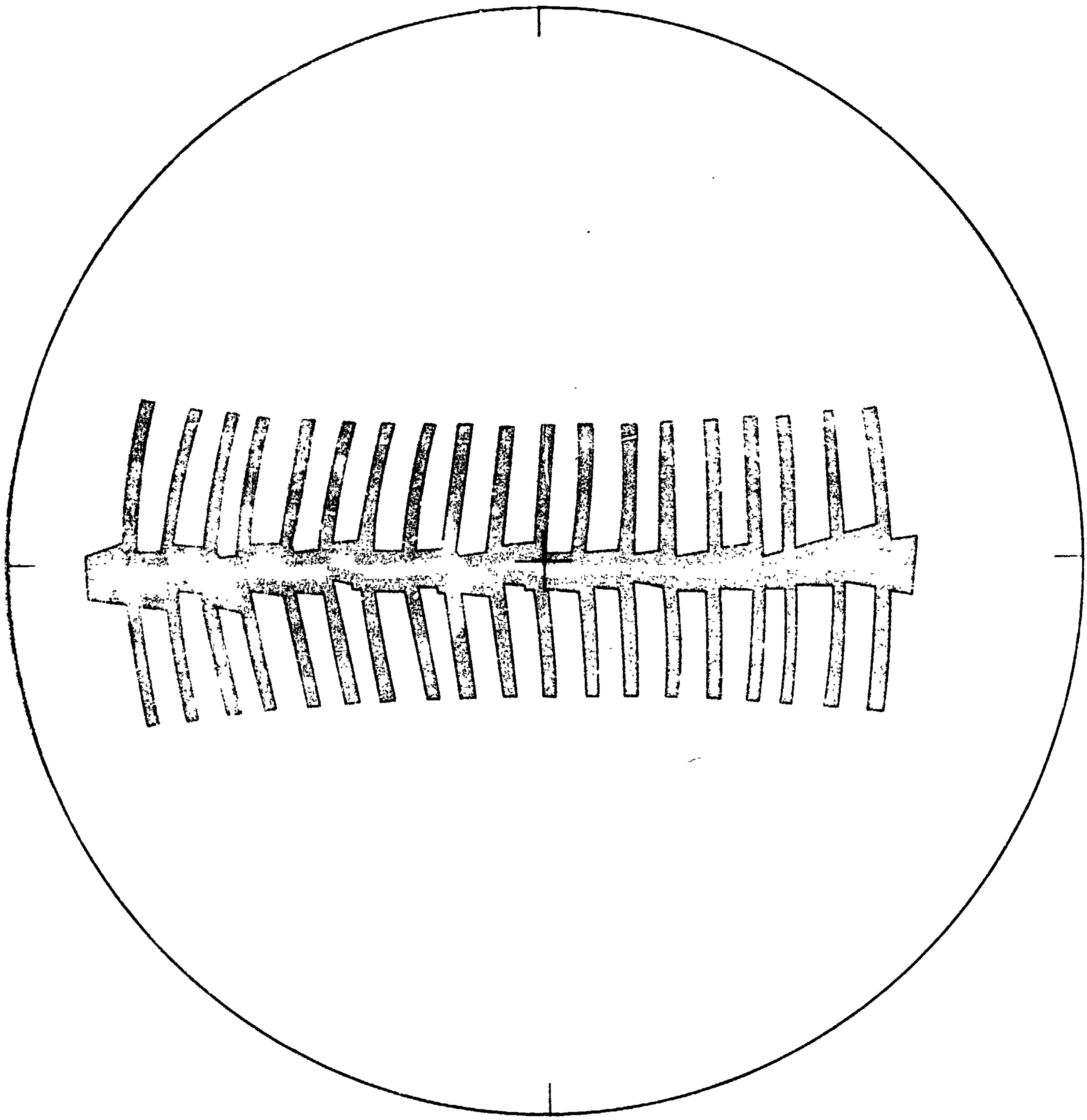
3.4.61 Improved Coordinates for Lunakhod 2 Based on Laser Observations from McDonald Observatory, Barker, Calame, Mulholland, Shelus, COSPAR Paper No. I.1.6; 1974

3.4.62 Triangulation for Large Scale Mapping From Apollo Panoramic Photography, Meier and Shull, DMATC; September 1974

3.4.63 Report on the Lunar Positional Reference System (1974), DMAAC; January 1975

3.5 CONTROL INDICES

INDEX NO.	DESCRIPTION
I(1)	Lunar Orbiter Regional System
I(2)	Landmark Tracking Regional System
I(3)	Apollo 10 and 12 Regional Systems
I(3a)	Apollo 15 (Apr 73) Regional System
I(3b)	Apollo 15 (Nov 73) and Apollo 17 Regional Systems
I(3c)	Laser Retroreflector Regional Systems
I(4)	Lunar Orbiter I and II and Apollo Local Systems
I(5)	Lunar Orbiter III and V Local Systems
II(1)	Landmark Tracking Regional System
II(2)	Apollo 10 Regional System
II(3)	Apollo 15 (Apr 73) Regional System
II(4)	Apollo 15 (Nov 73) and Apollo 17 Regional Systems

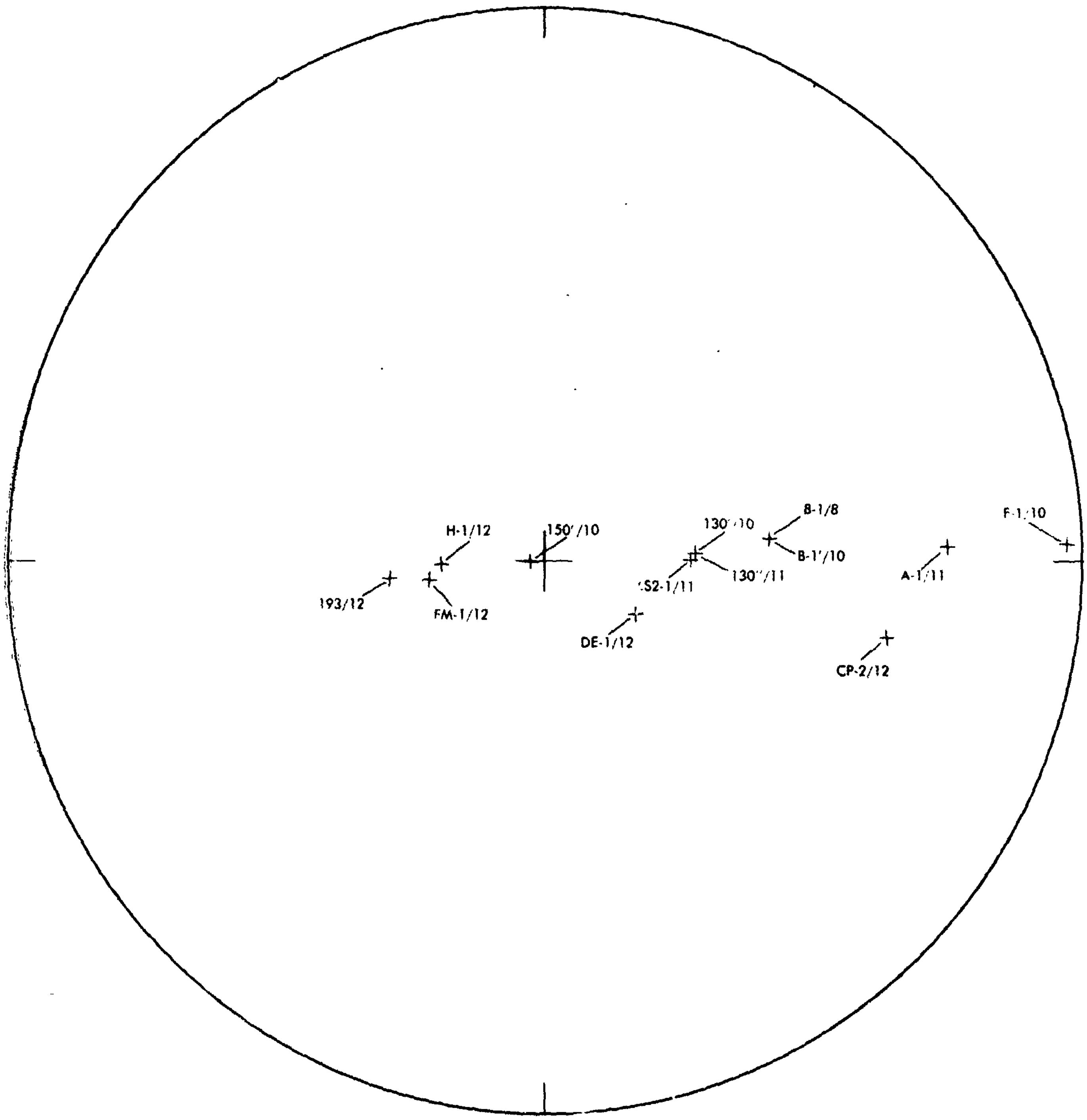


Earthside

REGIONAL CONTROL SYSTEM
Based on
LUNAR ORBITER MISSION
PHOTOGRAPHY

CONTROL INDEX NO. I (1)
DEC. 1972

Apollo Zone Triangulation



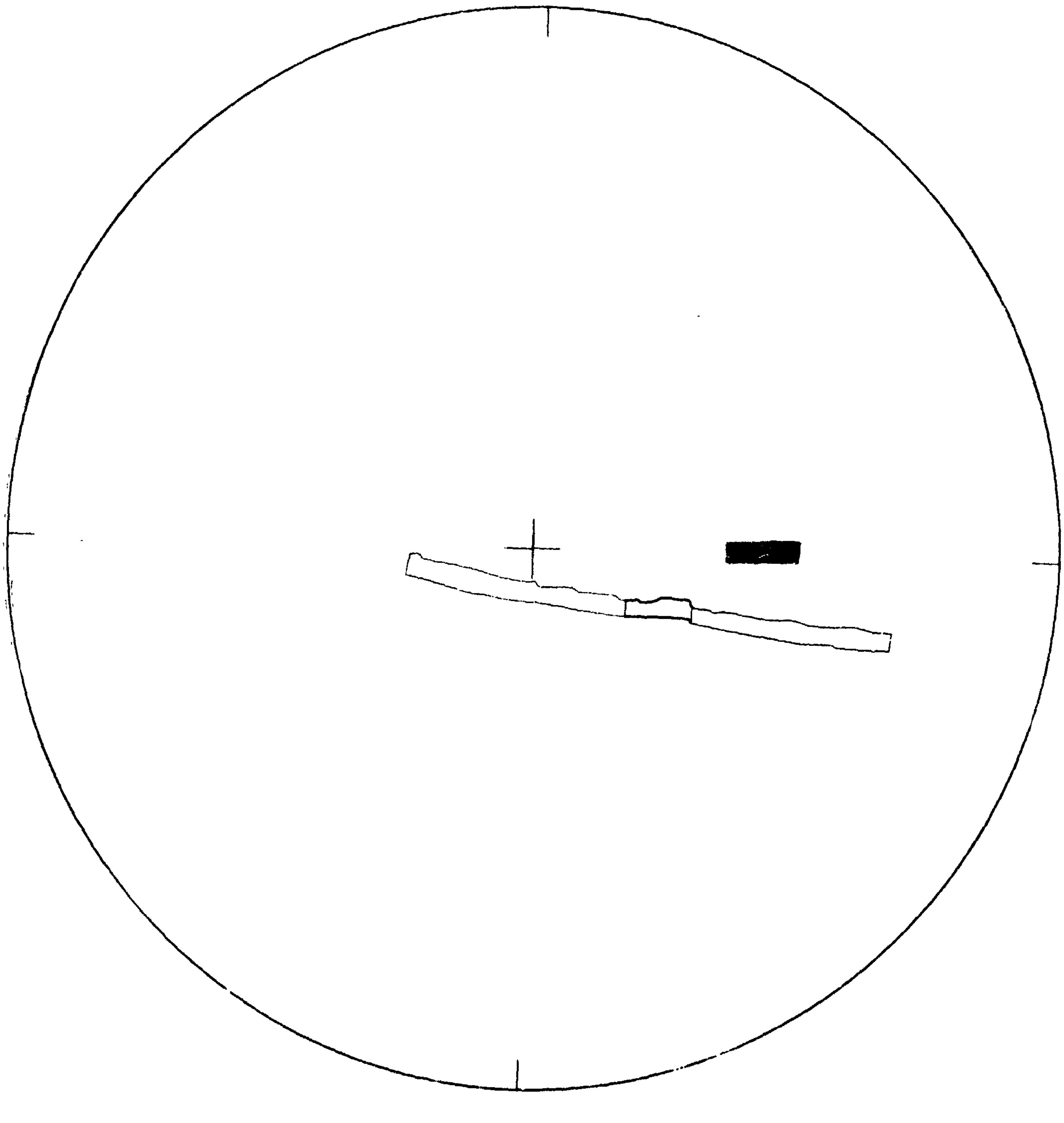
Earthside

REGIONAL CONTROL SYSTEM
Based on
APOLLO MISSIONS

Landmark Position. 130'/10 130'/11 Same location at this scale

CONTROL INDEX NO. 1 (2)

DEC 1972



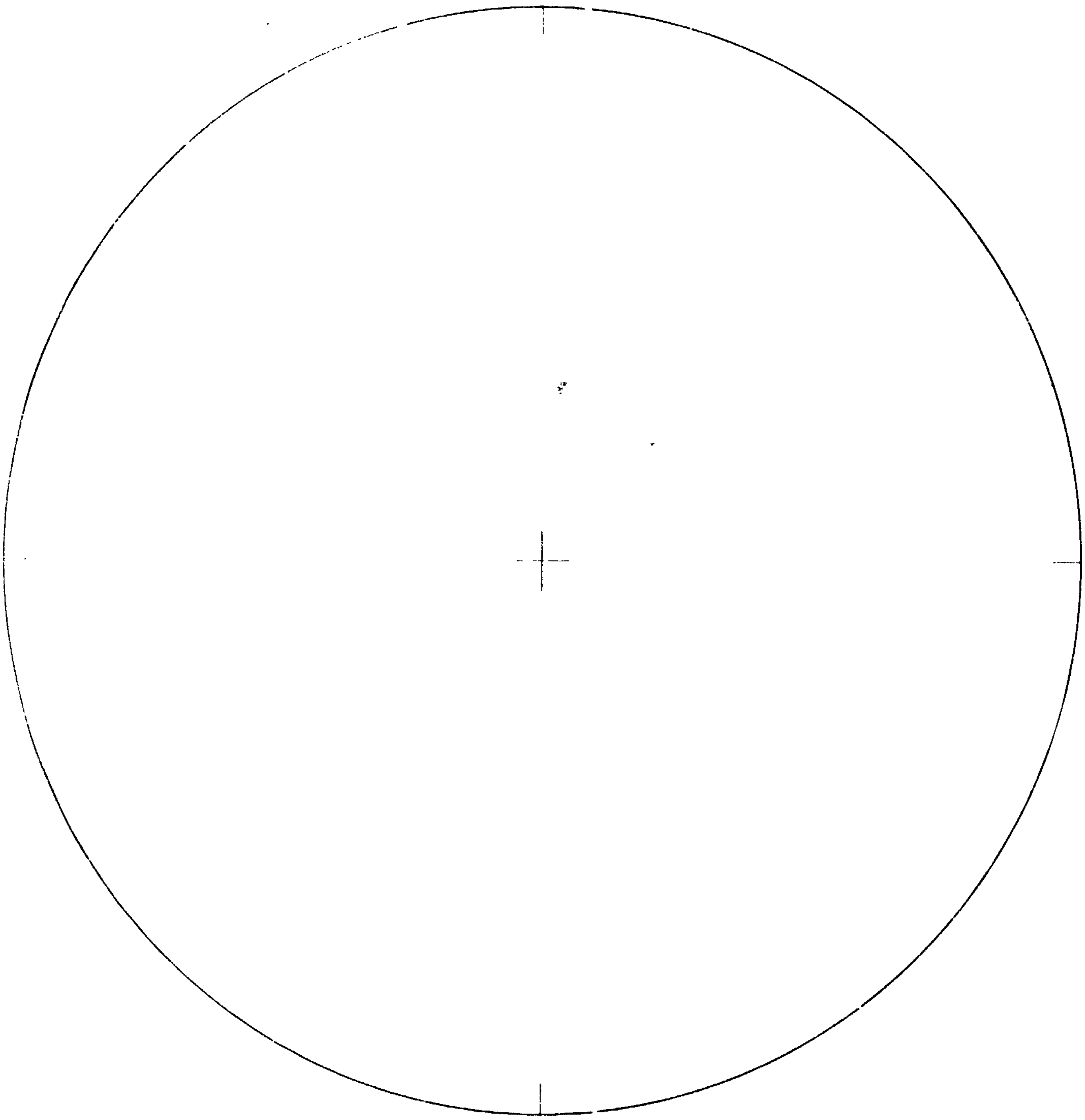
Apollo 10 ACIC (19[illegible])

Apollo 12 ACIC (1971)

Apollo 12 TOPOCOM (1971)

REGIONAL CONTROL SYSTEMS
Based on
APOLLO MISSION
PHOTOGRAPHY

CONTROL INDEX NO. I (3)
DEC. 1972



Earthside

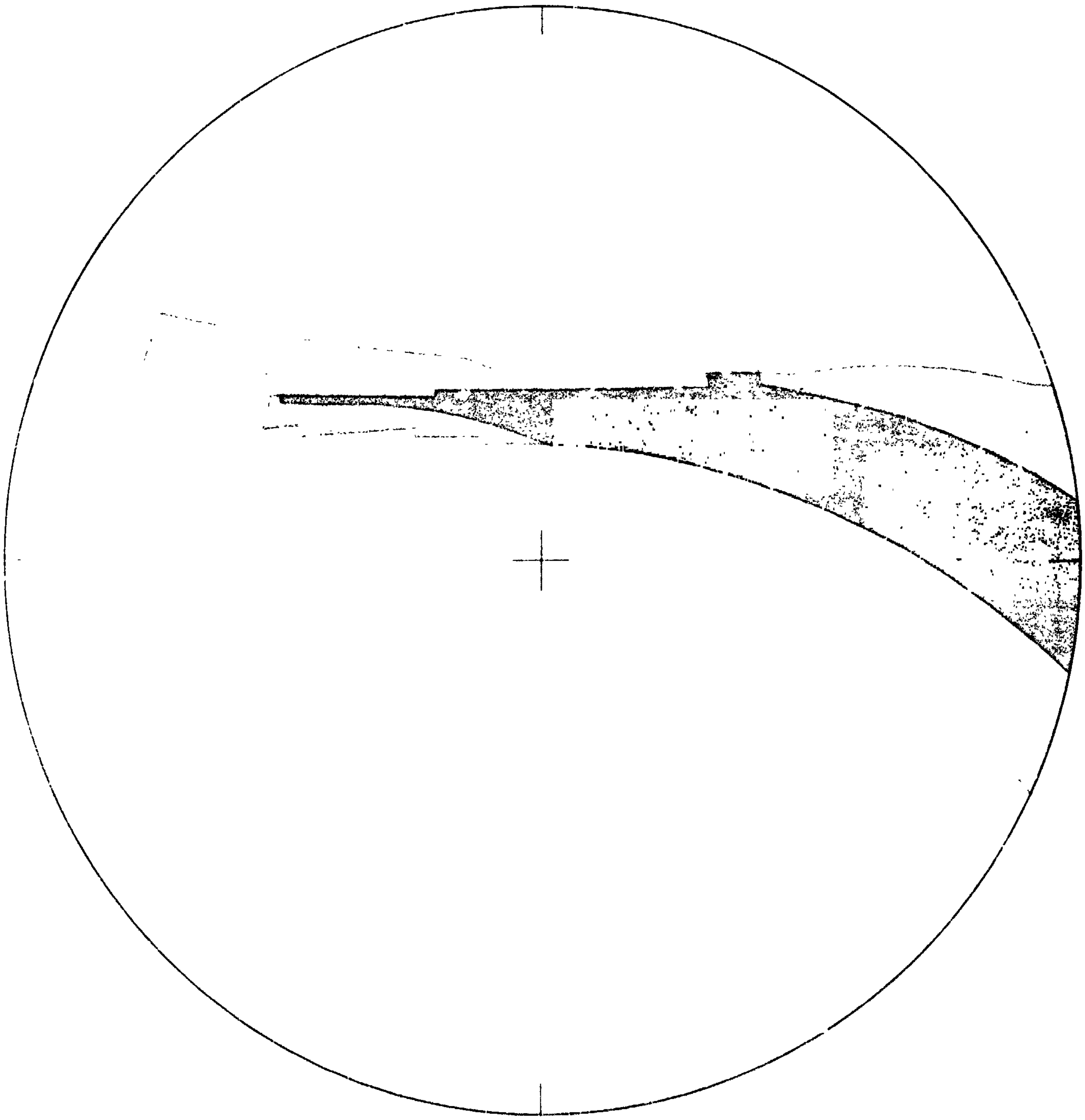
REGIONAL CONTROL SYSTEMS
(Earthside coverage)

Apollo 15 (April 1973)

Areas of Intensified Control

CONTROL INDEX NO. I (3a)

February 1975



Earthside

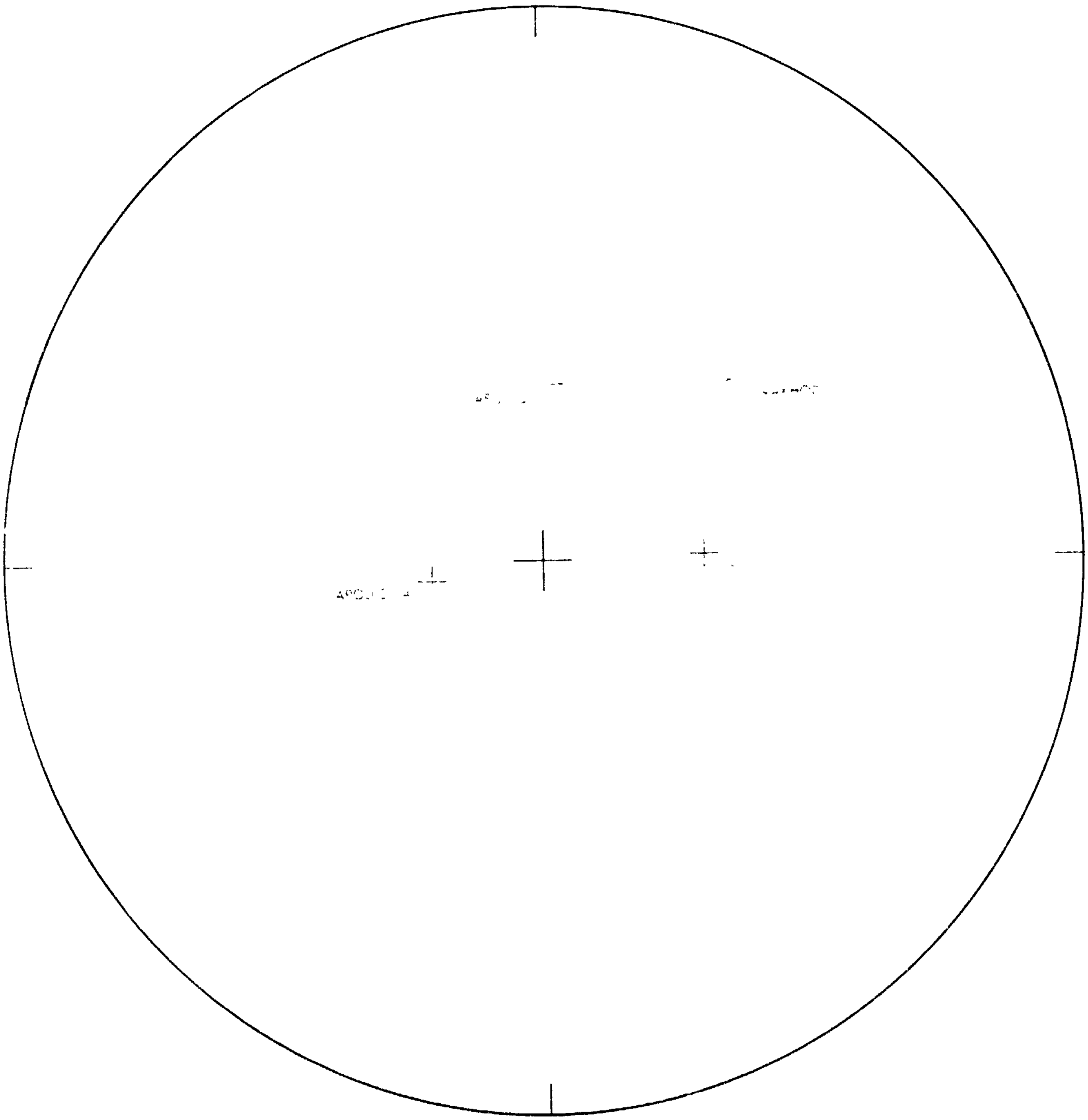
REGIONAL CONTROL SYSTEMS
(Earthside coverage)

Apollo 15 (Nov 1973)

Apollo 17 (1974)

CONTROL INDEX NO. I (3b)

February 1975

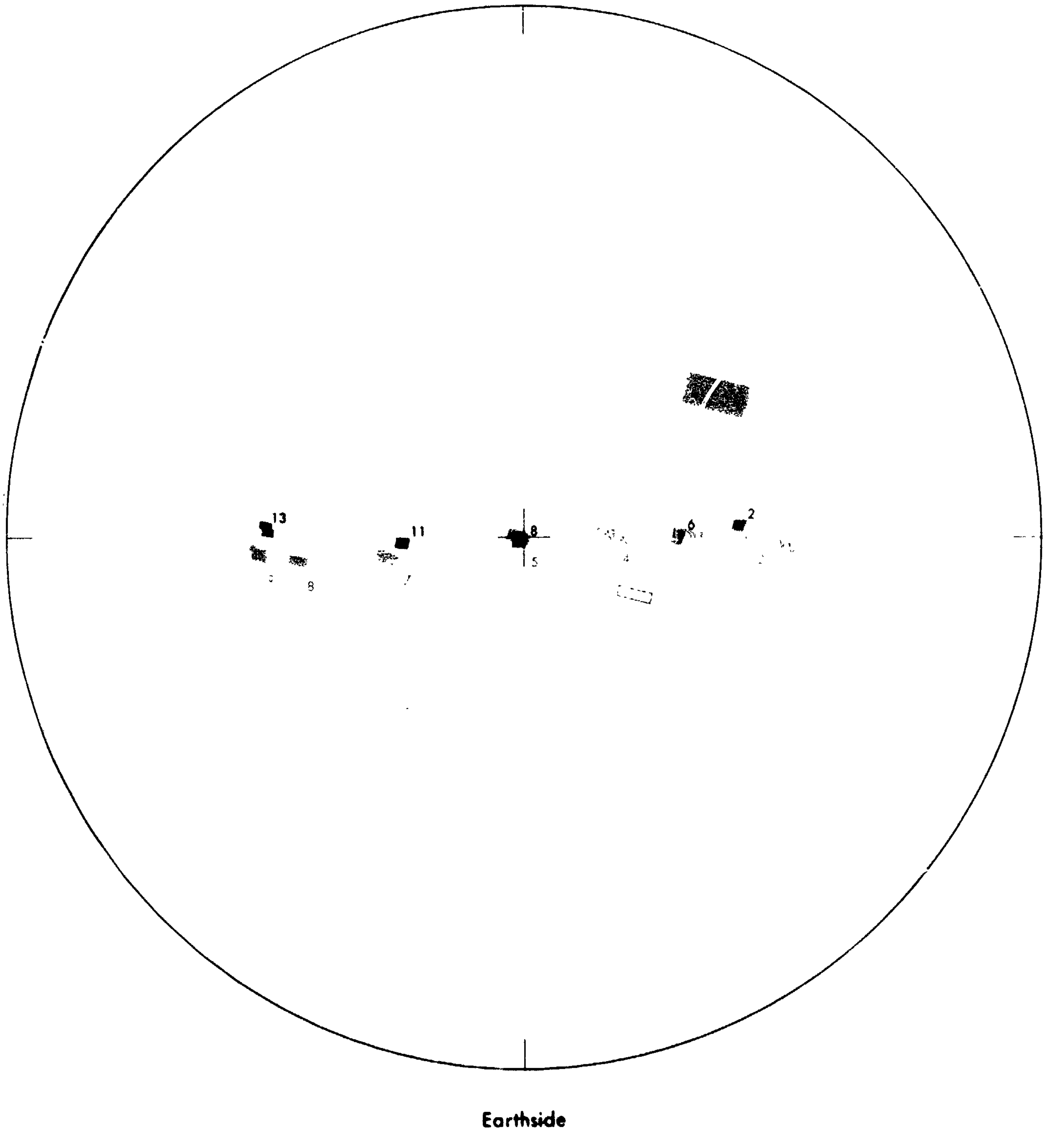


Earthside

REGIONAL CONTROL SYSTEM
BASED ON LASER
RETROREFLECTOR OBSERVATIONS

Laser Retroreflector Positions

CONTROL INDEX I (3c)
February 1975



Orbiter I Sites

Orbiter II Sites — 11 (Site No.)

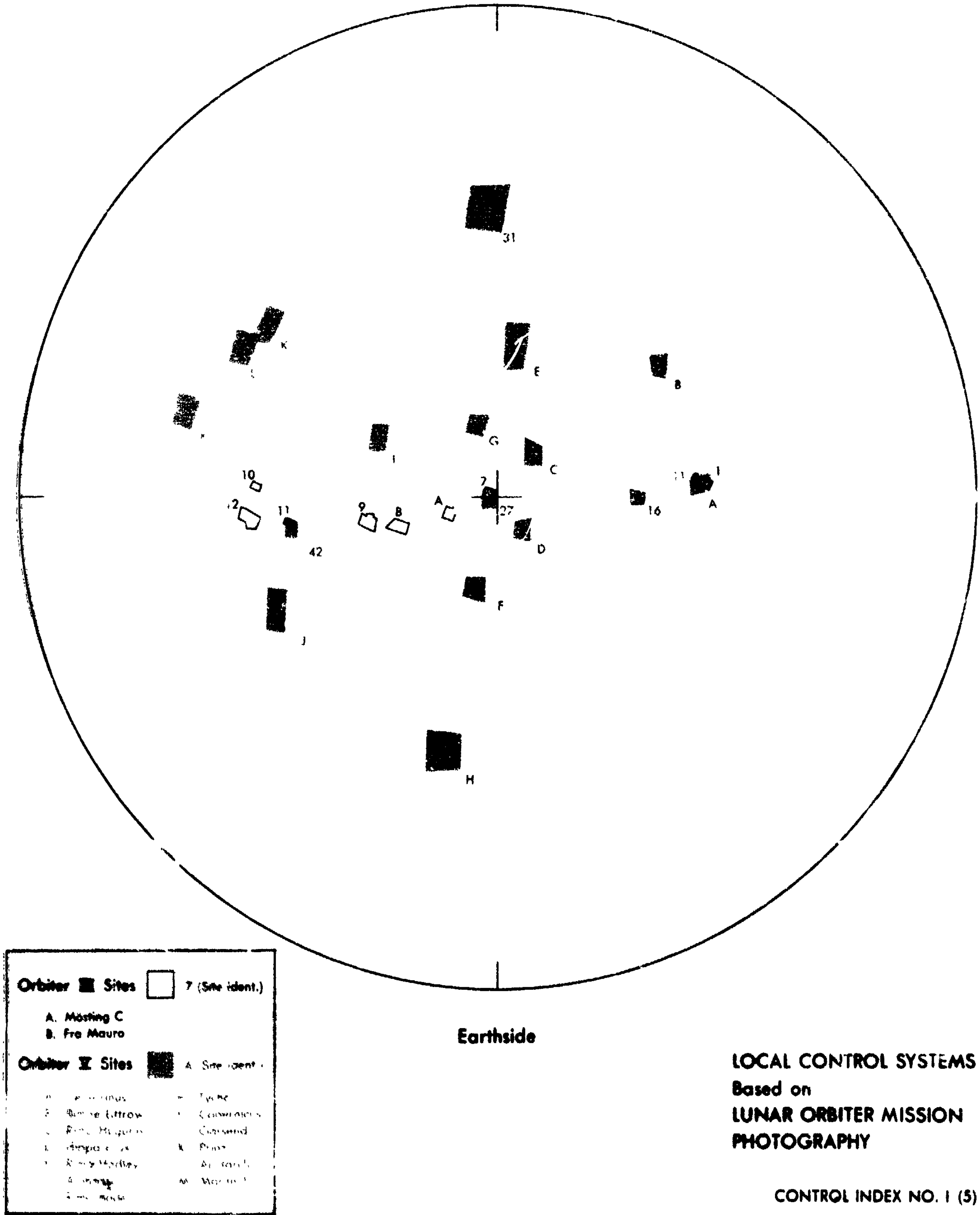
Site Taurus Littrow

Site Descartes

LOCAL CONTROL SYSTEMS

CONTROL INDEX NO. I(4)

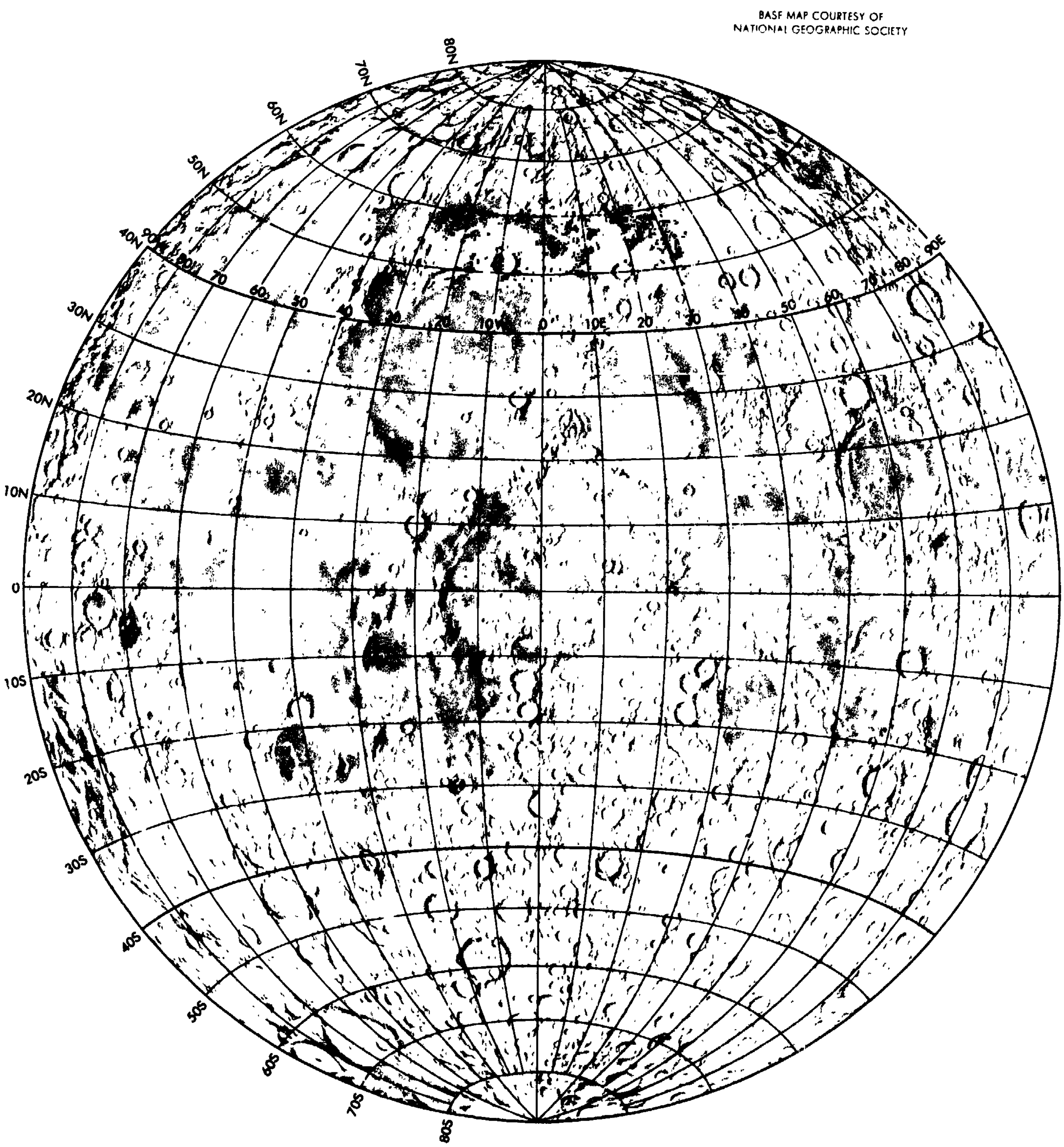
February 1975



LOCAL CONTROL SYSTEMS
Based on
LUNAR ORBITER MISSION
PHOTOGRAPHY

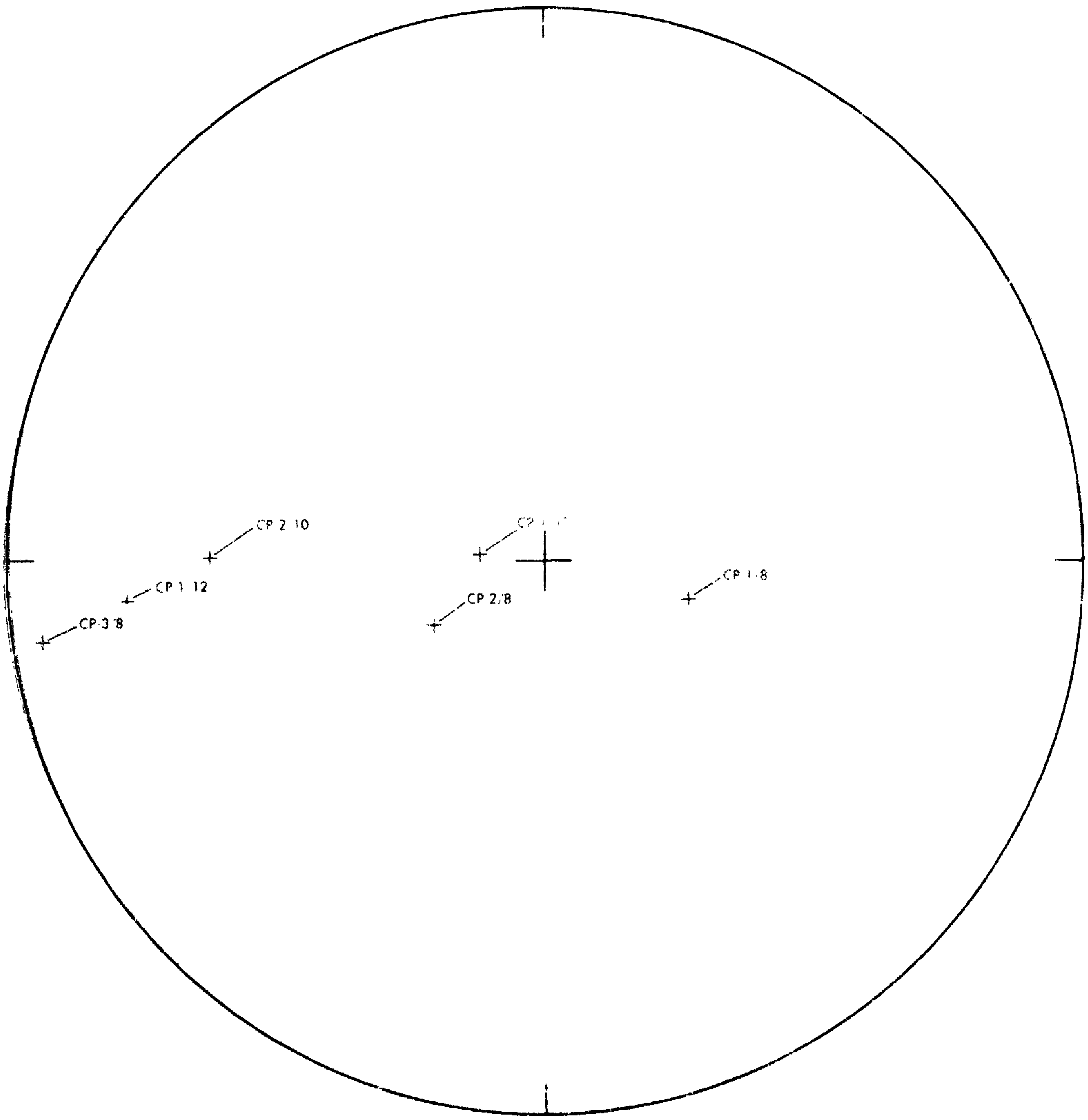
CONTROL INDEX NO. 1 (5)

DEC. 1972



BASE MAP COURTESY OF
NATIONAL GEOGRAPHIC SOCIETY
80N
70N
60N
50N
40N
30N
20N
10N
0
10S
20S
30S
40S
50S
60S
70S
80S
90W
80W
70
60
50
40
30
20
10W
0
10E
20
30
40
50
60
70
80
90E

Earthside



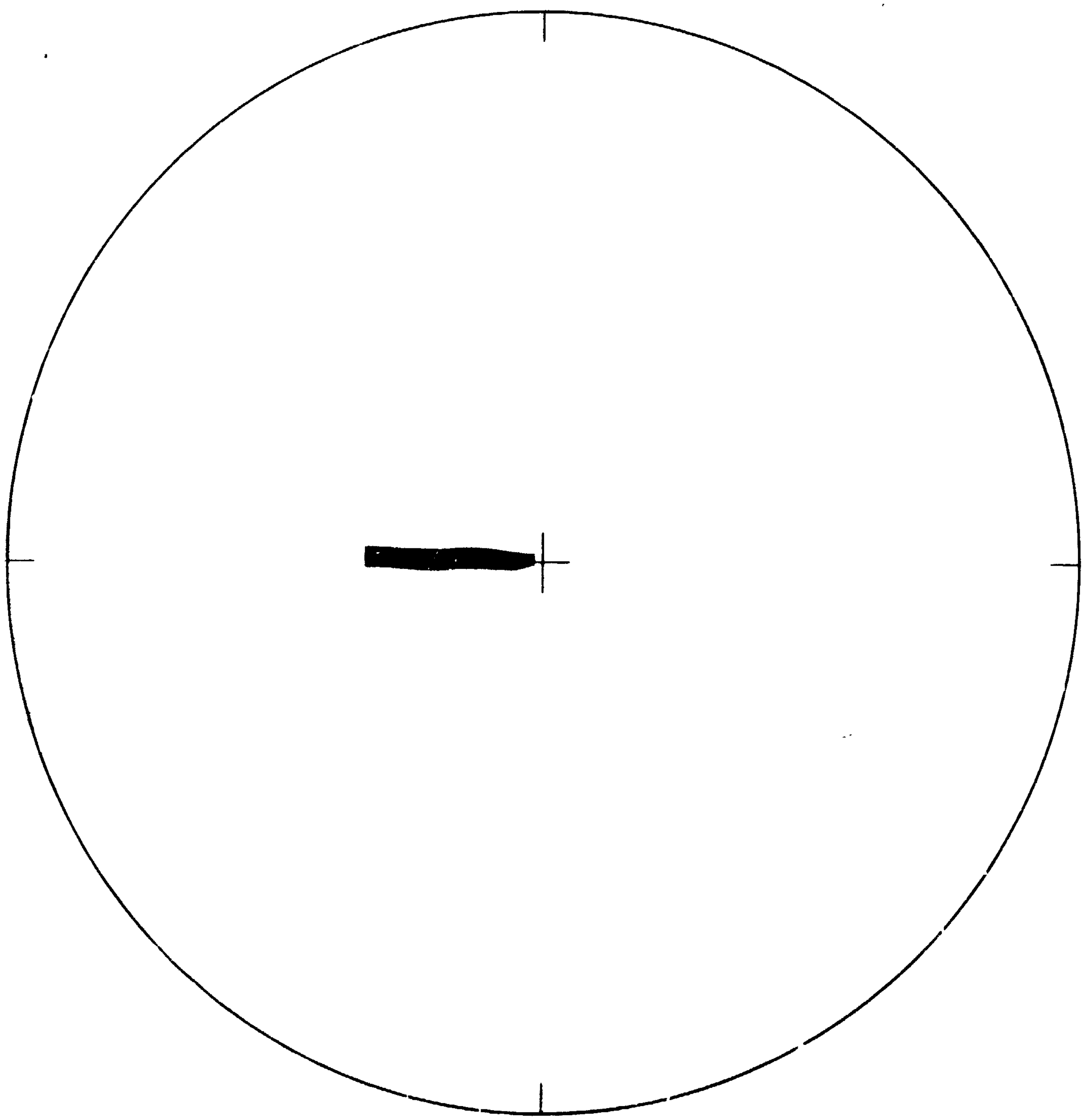
Farside

REGIONAL CONTROL SYSTEM
Based on
APOLLO MISSIONS

Landmark Positions

CONTROL INDEX NO. II (1)

DEC. 1972



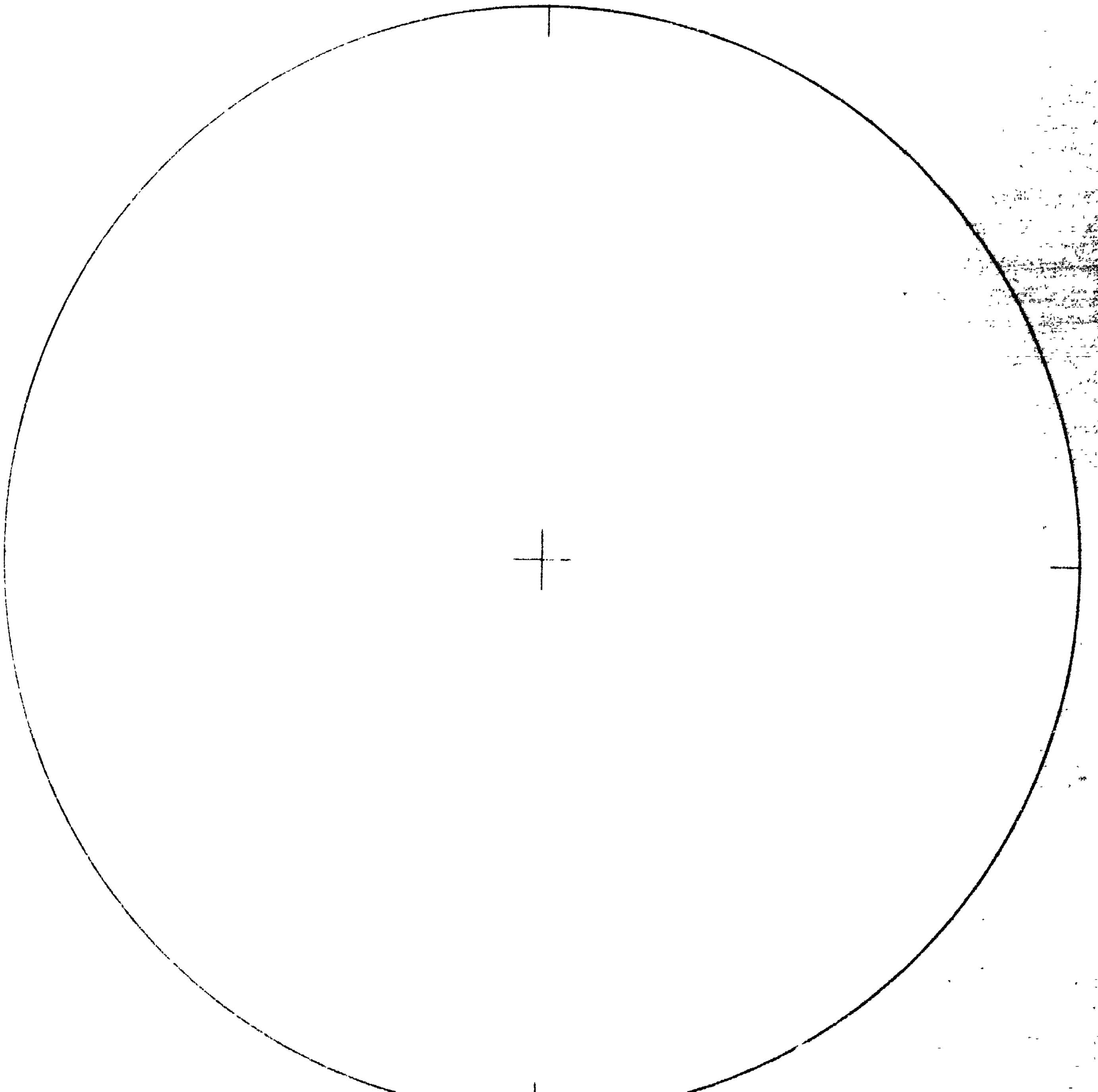
Farside

REGIONAL CONTROL SYSTEM
Based on
APOLLO MISSION
PHOTOGRAPHY

Apollo 10 DBA (1970) ■

CONTROL INDEX NO. II (2)

DEC. 1972



Farside

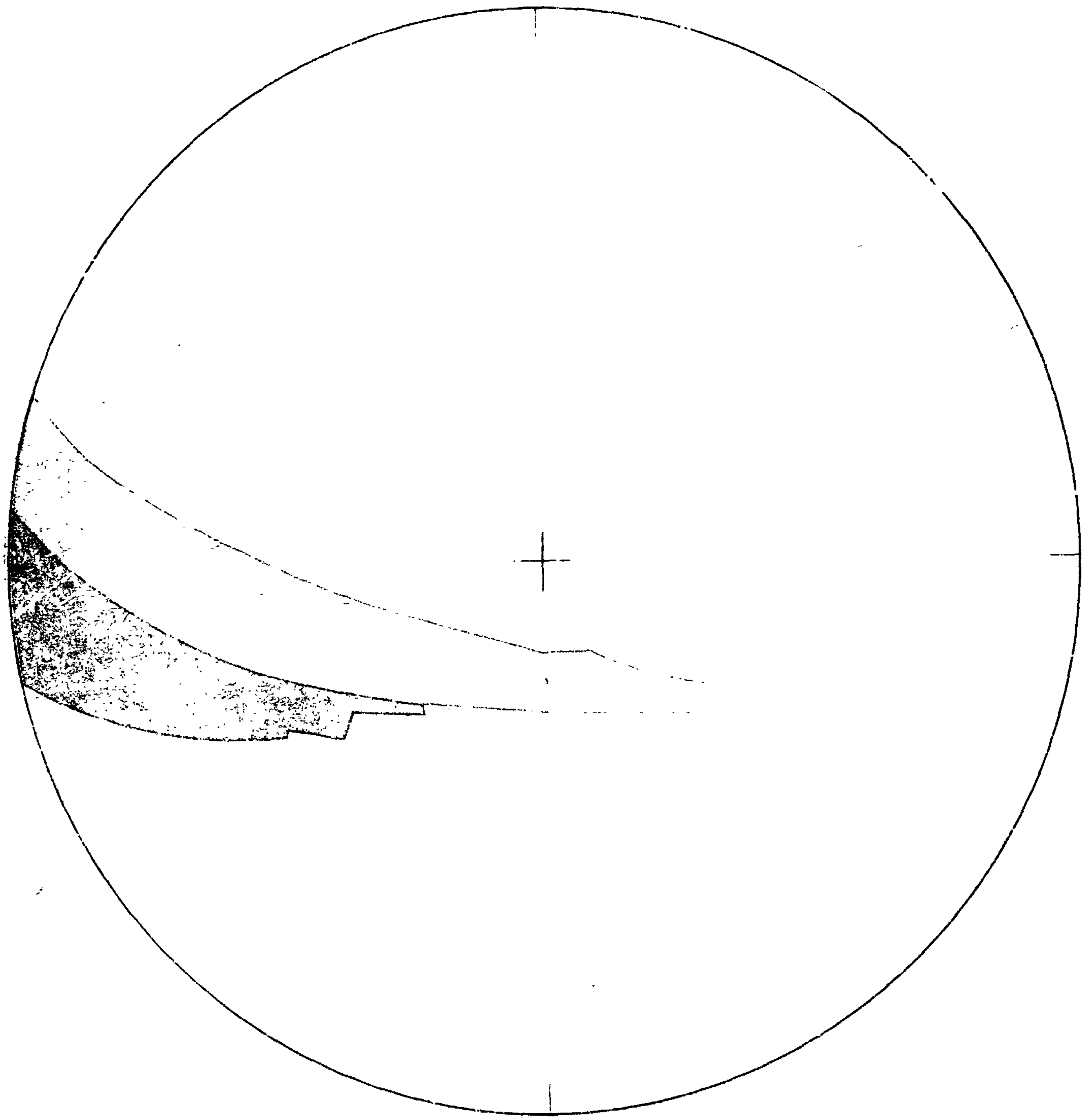
REGIONAL CONTROL SYSTEMS
(Farside coverage)

Apollo 15 (April 1973)

Areas of Intensified Control

CONTROL INDEX NO. II (3)

February 1973



Farside

REGIONAL CONTROL SYSTEMS
(Farside coverage)

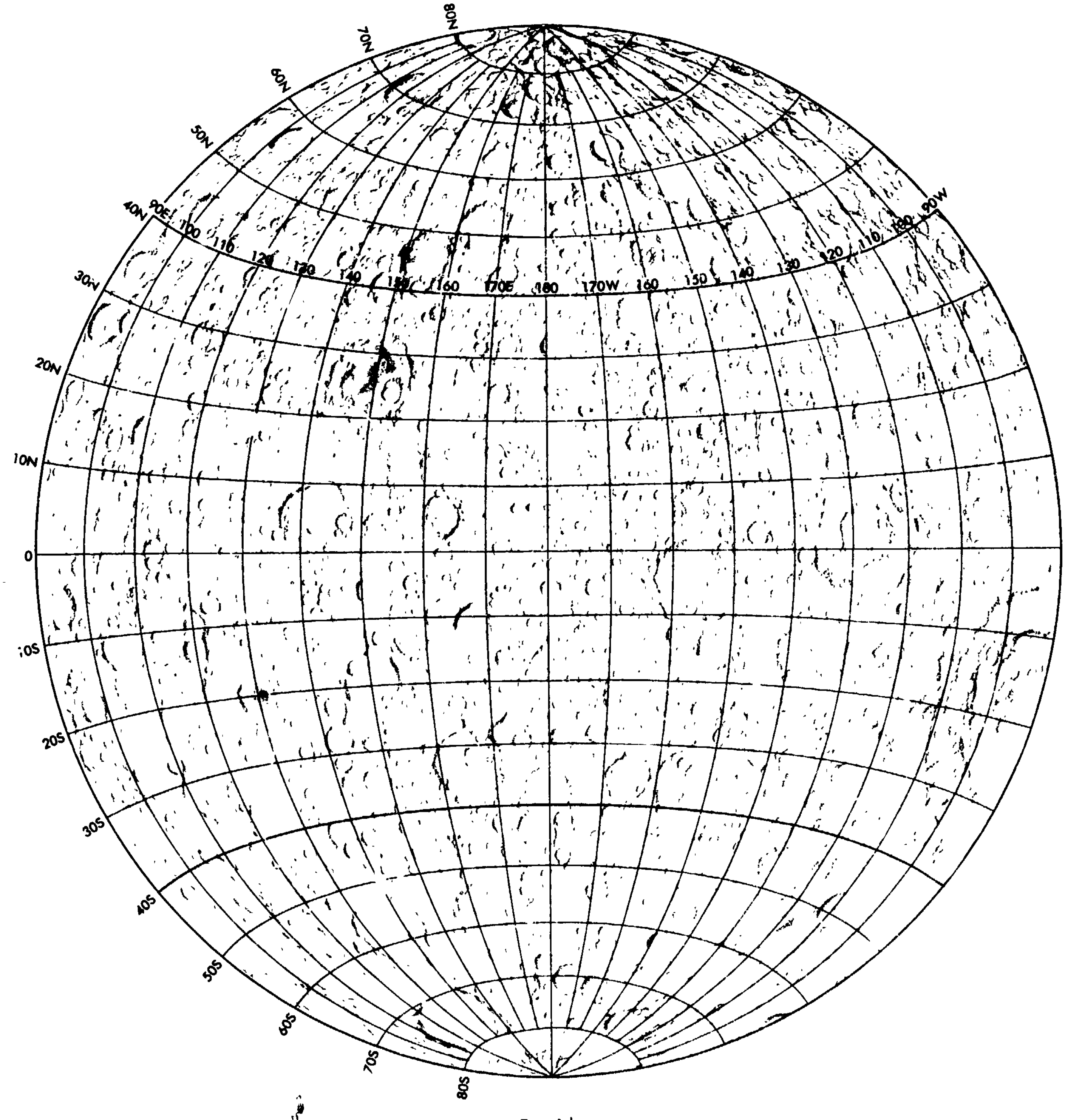
Apollo 15 (Nov. 1973)

Apollo 17 (1974)

CONTROL INDEX NO. II (4)

February 1975

BASE MAP COURTESY OF
NATIONAL GEOGRAPHIC SOCIETY



Farside

CONTROL INDEX BASE MAP NO. II

4.0 LUNAR MAPS, PHOTOMAPS AND PHOTO MOSAICS

The moon's surface does not lend itself to portrayal by symbols as used in earth mapping. Almost without exception, United States lunar cartographic works have pictorially expressed lunar terrain either through the direct use of photography or by artistic rendition. Modern lunar maps follow earth convention of North at the sheet top with prime meridian referenced to Crater Mosting A. In the past, U.S. lunar maps have expressed lunar longitude in terms of 0-180 degrees east (+) and 0-180 degrees west (-) of the prime meridian. In 1974, based on agreement between the U.S. National Aeronautics and Space Administration and the Academy of Sciences, USSR, NASA adopted a lunar longitude system of 360 degrees, proceeding counterclockwise from the prime meridian. More recently published lunar maps reflect this convention.

The production of lunar map products has generally responded to the availability of new and more definitive photographic source materials, only sometimes awaiting the development of improved control data to provide a like degree of positional precision. The following discussion of maps, photomaps and photo mosaics is categorized on the basis of product scale.

4.1 SMALL SCALE MAPS, PHOTOMAPS, AND PHOTOMOSAICS (1:2,000,000 and Smaller Scale)

Small scale lunar maps have served for reference and planning purposes as well as supporting regional studies. The information contained in the later date sheets has also been used as the basis for many specialized maps prepared in support of Apollo Missions.

The Lunar Planning Chart Series is recommended within its area of coverage for completeness of detail and positional accuracy. If use of a photographic base is advantageous, the Lunar Equatorial Zone Mosaics may be substituted. The Lunar Earthside, Farside, and Polar Chart Series represent the primary source of complete map coverage of the moon.

Lunar Planning Chart (LOC) Series 4.1.1

Lunar Equatorial Zone Mosaics (LEMC) Series 4.1.2

Lunar Earthside, Farside & Polar Chart (LMP) Series 4.1.3

"The Earth's Moon" 4.1.4

Lunar Charts LPC-1 & LFC-2 . . . . 4.1.5

USAF Lunar Reference Mosaics (LEM) 4.1.6

Lunar Earthside Maps 4.1.7

Apollo Zone Primary Sites Mosaic 4.1.8

4.1.1 LUNAR PLANNING CHART (LOC) SERIES
(Published by ACIC)

Lunar Planning Chart LOC-1
1st Edition, May 1971
Scale: 1:2,750,000
Projection: Mercator
Limits: 40°N-S, 40°W-140°W
Size: 41.5 x 44.5 in.

Lunar Planning Chart LOC-2
1st Edition, May 1971
Scale: 1:2,750,000
Projection: Mercator
Limits: 40°N-S, 50°E-50°W
Size: 41.5 x 44.5 in.

Lunar Planning Chart LOC-3
1st Edition, May 1971
Scale: 1:2,750,000
Projection: Mercator
Limits: 40° N-S, 40°E-140°E
Size: 41.5 x 44.5 in.

Lunar Planning Chart LOC-4
1st Edition, May 1971
Scale: 1:2,750,000
Projection: Mercator
Limits: 40°N-S, 130°E-130°W
Size: 41.5 x 44.5 in.

Lunar Planning Chart LOC-2 (obsolete)
1st Edition, July 1969
Scale: 1:2,500,000
Projection: Mercator
Limits: 25°N-S, 50°E-50°W
Size: 28.5 x 49 in.

Lunar Planning Chart LOC-3 (obsolete)
1st Edition, July 1969
Scale: 1:2,500,000
Projection: Mercator
Limits: 25°N-S, 40°E-140°E
Size: 28.5 x 49 in.

Lunar Planning Chart LOC-4 (obsolete)
1st Edition, July 1969
Scale: 1:2,500,000
Projection: Mercator
Limits: 25°N-S, 130°
Size: 28.5 x 49 in.

The LOC planning series was designed to satisfy the following requirements:

1. To cover the Apollo area of interest.
2. To provide increased density of feature detail than shown on the 1:5,000,000 LMP series.
3. To show all primary and secondary approved IAU names.
4. To serve as a common base for the various Apollo mission charts.

Compilation of the LOCs was initiated in 1968 based upon Lunar Orbiter photography flown in 1966-67, supplemented by Hasselblad coverage from Apollo Missions 8 and 10. Earthbased telescopic full moon photographs were used as source for albedo patterns and ray structure. Details from LAC charts were also used to the extent of their coverage.

The ACIC Selenodetic System (1965), supplemented by the Apollo Zone Triangulation (1969), was the primary control basis for the lunar earthside areas. The Positional Reference System (1969) was used for control of lunar limb and farside regions.

The compilation procedure required the mosaicking of rectified orbiter photography to a control plot. This resulted in a controlled photo base from which lunar relief was portrayed by airbrush techniques using an assumed east lighting. The final charts were lithographed in colors of brown, blue and black.

The original LOCs, published in July 1969, were limited to 25°N-S latitude and only three charts were completed. Numbers were used to designate lunar farside features since IAU names for this area were not approved until a year later. Prior to initiating production on the last chart in this series, LOC-1, it was decided to extend the latitude coverage to 40°N-S. Work was then directed toward adding another 15°N-S to the existing charts and producing LOC-1. However, after extending the latitude limits to 40°N-S, the scale had to be reduced to 1:2,750,000 because of press size limitations.

The revised LOCs, including the new LOC-1, were published in May 1971. The litho colors are the same as the original LOCs; however, the shaded relief was enhanced by the duotone process. This series of charts is the best available lunar coverage at this scale. Also, it is the only chart series with complete up-to-date nomenclature.

In support of Apollo missions, the LOCs were used as a base for the Lunar Orbital Science Flight Chart, scale 1:2,750,000, the Apollo Lunar Orbit Chart, scale 1:11,000,000, and the Apollo Photographic Index Map, scale 1:5,000,000.

Area coverage of these map sheets is reflected in Map Indexes I(2) and II(2).

4.1.2 LUNAR EQUATORIAL ZONE MOSAICS
(Published by USATOPOCOM)

Lunar Equatorial Zone Mosaics
1st Edition December 1968
Scale: 1:2,500,000
Limits: 15°N-15°S, 0°-360° longitude
Number of Sheets: 4
Sheet Size: 14.5" x 38"

Lunar Equatorial Zone Mosaics
1st Edition November 1969
Scale: 1:2,500,000
Projection: Mercator
Limits: 20°N-20°S, 0°-360° longitude
Number of Sheets: 4
Sheet Size: 24" x 45"

The controlled Lunar Equatorial Zone photomosaics provide complete coverage of the lunar equatorial zone based on Lunar Orbiter I-V photographic records. using both medium and high resolution photographs. The four sheets in the series cover the Earthside (#1), Farside (#2), Eastern Limb (#3), and Western Limb (#4). Each is printed without lunar nomenclature, containing only a white-masked projection with values.

The ACIC Selenodetic System (1965), supplemented by the Apollo Zone Triangulation (1969), was the primary control basis for the lunar earthside areas of the 1969 edition. The Positional Reference System (1969) was used for control of lunar limb and farside regions.

Each sheet is printed with a representative pattern of parent crater and secondary crater names for the earthside and limb areas in white-masked type. The farside nomenclature reflects the interim numbering system established for use in referencing significant surface features as the International Astronomical Union (I.A.U.) did not establish farside nomenclature until 1970. Bar scales, an index of photographs used, and control information are available in the chart margin.

The 1969 edition is preferred with respect to both extent of coverage and accuracy of feature positions.

Area coverage provided by these photo mosaics is reflected in Map Indices I(3) and II(3).

4.1.3 LUNAR EARTHSIDE, FARSIDE & POLAR CHARTS (LMP) SERIES
(Published by ACIC)

Lunar Earthside Chart LMP-1
1st Edition, January 1970
2nd Edition, October 1970
Scale: 1:5,000,000
Projection: Mercator
Limits: 50°N-S, 100°W-100°E
Size: 29 x 41 in.

Lunar Farside Chart LMP-2
1st Edition, January 1970
2nd Edition, October 1970
Scale: 1:5,000,000
Projection: Mercator
Limits: 50°N-S, 80°E-80°W
Size: 29 x 41 in.

Lunar Polar Chart LMP-3
1st Edition, January 1970
2nd Edition, October 1970
Scale: 1:5,000,000
Projection: Polar Stereographic
Limits: 45°N-90°N, 360°
45°S-90°S, 360°
Size: 29 x 47 in.

Lunar Earthside Chart LEC-1 (obsolete)
1st Edition, July 1968
Scale: 1:5,000,000
Projection: Mercator
Limits: 48°N-S, 100°W-100°E
Size: 27 x 42 in.

Lunar Farside Chart LFC-1 (obsolete)
1st Edition, August 1967
2nd Edition, October 1967
Scale: 1:5,000,000
Projection (Front of Chart) Mercator
Limits: 48°N-S, 80°E-80°W
Projection (Back of Chart) Gnomonic
Limits: 48°N-90°N, 180°
48°S-90°S, 180°
Size: 27 x 39 in.

LFC-1 (obsoleted by LMP-2) was the first Farside chart to be compiled from Lunar Orbiter photography. The original LFC-1, published in August 1967 for distribution at the August IAU meeting in Prague was based on Lunar Orbiter I, II, III, IV and USSR Zond 3 photography. At that time, photography was lacking for some 20% of the Farside area which resulted in LFC-1 being published with some holiday areas. Photography for the missing areas was acquired by Lunar Orbiter V which allowed LFC-1 to be reissued in October 1967 with complete hemispherical coverage. Also, Lunar Orbiter V replaced the Zond 3 coverage.

The position of features on LFC-1 was considered as provisional, having been independently determined from predicted coordinates of the principal points of the Lunar Orbiter photographs. Topography was portrayed by air brush shaded relief with an assumed lighting from the west. The Farside polar areas, from 48°N-S to the poles, were printed on the reverse side of LFC-1.

LEC-1 (obsoleted by LMP-1) was compiled as a companion chart to LFC-1 in order to provide similar coverage of the Earthside hemisphere. The LACs were used as source for this chart, supplemented by Lunar Orbiter photography in the limb regions. However, the polar areas for the Earthside hemisphere were not compiled because at that time, plans were being formulated to completely recompile LFC-1 and LEC-1 based on a new network of control. The Positional Reference System (1969) provided the required control basis for limb and farside areas with the ACIC Selenodetic System (1965) being the primary control source used for central earthside coverage of the LMP series.

The LMP charts provide complete coverage of the lunar sphere and serve as a basic reference/planning series. In the compilation process, maximum utilization was made of existing LOC drawings (LOCs 2, 3, and 4, 25°N-S) reduced to the LMP scale and redrawn. For the remaining areas, Orbiter photographs were reduced, rectified and paneled to the control. This formed the base for drawing the shaded relief. In the shaded relief rendering the conventional west lighting was changed to an east lighting in order to closely approximate shadows as would be seen on the Earthside of the moon during an Apollo mission flight. The relief was printed in brown, highlighted by ray patterns and albedo background, compiled from Earthbased photography and printed in blue.

The LMP series was first published in January 1970 but without names for the Farside features. Following the IAU General Assembly in August 1970, a second edition was issued in October 1970 which included the newly approved Farside names. However, some minor name changes have occurred since the October 1970 edition was distributed.

LMP-1 and LMP-2 are constructed on a Mercator projection with true scale at 34°N-S latitude. Thus, the scale at the equator is 1:6,035,533. LMP-3 contains both the north and south polar areas on the same chart. These areas are compiled on a Polar Stereographic projection with true scale tangent at the poles. LMP-1, 2 and 3 have a common scale at 45°N-S latitude.

The LMP series represents the best available 1:5,000,000 scale map coverage of the entire lunar surface. Coverage of this series is shown in Map Indices I(1) and II(1).

4.1.4 "THE EARTH'S MOON"
(Published by the National Geographic Society)

"The Earth's Moon"
1st Edition February 1969
Scale: 1:11,620,000 (mean scale)
Projection: Lambert Azimuthal Equal-Area
Limits: 90°N-S 90°E-W
Sheet Size: 28" x 42"

"The Earth's Moon" presents the near and farside hemispheres of the moon in a single sheet with lunar topography portrayed by shadient relief in blue and gray tones.

This map was compiled from Lunar Orbiter Mission photography and Photo Support Data. In the compilation process, a latitude and longitude grid was applied to each Orbiter photograph used as source for the rendition of the hemisphere drawings. This was accomplished by photographing a globe having an inscribed projection, from a position and direction which corresponded to the Photo Support Data's definition of spacecraft camera and moon relationship. Each image of the grid represented the same perspective view as its respective photograph. Composites of the individual grids and photographs were used to define the positions of features portrayed.

The map body contains considerable supplemental lunar and general interest information including a names index, diagrams of the earth-moon-sun relationship, lunar data notes and positions of 22 spacecraft which have landed on or impacted the moon.

The equal area characteristics of the projection used minimizes distortions in limb areas, and portrayal by hemispheres employed has resulted in a very good general purpose lunar reference map. In fact, the base maps supporting indexes appearing in this Dossier are reduced copies of the lunar hemispheres portrayed in "The Earth's Moon."

4.1.5 LUNAR CHARTS LPC-1 & LFC-2
(Published by ACIC)

Lunar Chart LPC-1
1st Edition, March 1970
Scale: 1:10,000,000
Projection: Equatorial Area - Mercator
Polar Areas - Stereographic
Limits: Complete Lunar Coverage
Size: 26 x 38 in.

Lunar Farside Chart LFC-2 (obsolete)
1st Edition, August 1967
Scale: 1:10,000,000
Projection: Equatorial Area - Mercator
Polar Areas - Gnomonic
Limits: Farside Hemisphere
Size: 23 x 29 in.

The Lunar Farside Chart, LFC-2, is a photographic reduction of LFC-1 to a scale of 1:10,000,000. This was the first lunar chart published at this scale. True scale is at 30°N-S and 70°40' N-S. The equatorial Mercator section, 48°N-S, was positioned in the center of the chart with two polar hemispheres located north and south, tangent at 180°. A black background surrounds the chart imagery and contains two masked areas in white, one showing general notes and the other an index of photo coverage. Topography was printed in green -- the same color as LFC-1. Nomenclature consists only of a few earthside names within the limb regions.

LFC-2 contains the same holiday areas as the 1st edition LFC-1. Also, it was never revised when the missing topography became available. Accordingly, LFC-1 soon became obsolete.

The availability of the LMP series in January 1970 afforded an opportunity to publish a new 1:10,000,000 scale lunar chart. Therefore, LPC-1, produced from LMP-1, 2 and 3, came into being in March 1970. In assembling LPC-1, it was decided to center the equatorial Mercator area on the first meridian. This decision resulted in splitting LMP-2 at 180° and adding each half to the east and west sides of LMP-1. Also, to permit a rolling fit to the two polar areas, positioned in the upper half of LPC-1, the 5° overlap on LMP-1 and 2 (45° to 50° N-S) was deleted.

LPC-1 was printed in brown and blue against a black background similar to LFC-2. All primary features were named with the exception of Farside names which had not been approved. In October 1970 when the Farside names became available, LPC-1 was not reissued. Consequently, this is an area of deficiency on the current edition of LPC-1.

A special NASA edition of LPC-1 was issued in August 1970 in support of the 14th IAU General Assembly. Overprinted in purple were unofficial new names proposed by the IAU Lunar Nomenclature Committee. This special edition was printed in limited quantities and only file copies remain in existence.

4.1.6 USAF LUNAR REFERENCE MOSAIC
(Published by ACIC)

USAF Lunar Reference Mosaic LEM-1
Advance Edition, February 1960
1st Edition, November 1960
2nd Edition, November 1962
3rd Edition, July 1966
Scale: 1:5,000,000
Projection: Orthographic
Limits: Lunar Diameter 27 in.
Size: 34 x 35 in.

USAF Lunar Wall Mosaic LEM-1B
1st Edition, January 1963
2nd Edition, July 1966
3rd Edition, November 1969
Scale: 1:2,500,000
Projection: Orthographic
Limits: Lunar Diameter 55.5 in.
Size: 58 x 70 in.

USAF Lunar Reference Mosaic LEM-1A
Advance Edition, February 1960
1st Edition, February 1960
2nd Edition, November 1962
3rd Edition, July 1967
Scale: 1:10,000,000
Projection: Orthographic
Limits: Lunar Diameter 13.5 in.
Size: 17 x 18 in.

The USAF Lunar Reference Mosaic, LEM (Lunar Earthside Mosaic) is a composite photo mosaic of the moon produced from selected photographs taken at Mt. Wilson, McDonald and Pic du Midi Observatories. Sections of twenty-four photographs were chosen which would provide a constant sun angle in order to maintain a uniform portrayal of lunar craters and prominences.

This mosaic was compiled to an orthographic projection which shows the moon as a sphere as viewed from an infinite distance. Position was determined through the use of selenographic control established primarily from the measures of Franz and Saunder as compiled in the Orthographic Atlas of the Moon, edited by G. P. Kuiper in 1960. Each photograph was copied to a common scale and rectified to mean libration in order for it to match or fit adjacent sections.

The USAF Lunar Reference Mosaic was originally compiled in February 1960 and published at the 1:5,000,000 scale. In 1962 it was recompiled with improved photo imagery and issued in the three existing sizes. Subsequent revisions have been limited to updating names.

This series of lunar mosaics have been one of the most popular items in the lunar map inventory. They have been very much in demand for use as a wall display and as a base for various indices.

All three sizes of LEM are lithographed in duotone blue and gray against a solid black background.

4.1.7 LUNAR EARTHSIDE MAPS
(Published by USATOPOCOM)

Topographic Lunar Map
1st Edition, September 1964
Scale: 1:5,000,000
Projection Modified Stereographic
Limits: 90°N-S, 180°
Number of Sheets: 2
Sheet Size: 54" x 38"

Topographic Lunar Map
1st Edition, June 1965
Scale: 1:2,000,000
Projection Modified Stereographic
Limits: 90°N-S, 180°
Number of Sheets: 6
Sheet Size: 54" x 38"

Mare Nectaris - Mare Imbrium
1st Edition, March 1962
Scale: 1:2,500,000
Projection Modified Stereographic
Limits: 40°N-S, 40°E-40°W
Number of Sheets: 1
Sheet Size: 54" x 32"

Lunar earthside maps were produced to provide full topographic map coverage pending the availability of spacecraft photography of the moon, and to assist in the planning of early lunar missions such as those of the Ranger and Orbiter series. These maps were produced in separate Shaded Relief, Relief, and Gradient Tint versions. The contour interval is 1000 meters with supplementary contours at 500 meter intervals. Relief is shown by form lines in some areas.

Eight pairs of photographs taken at Paris Observatory between March 1896 and January 1907 were used as compilation source. The photographs of each pair were taken near the extreme longitude librations of ± 7°54'. The pairs of photos were thus stereo pairs with an effective baseline of about 65,000 miles. The scale of the source photography is about 1:22,000,000.

The control used in the compilation of these maps consisted of the coordinates of 150 points determined by Schrutka-Rechtenstamm in 1958 described in Section 3.1.2. The horizontal datum was the crater Mosting A, which was assigned latitude 3°10'47" south and longitude 354°50'13", based on Schrutka-Rechtenstamm control. Mosting A was also chosen as the vertical datum. However, it was considered desirable to avoid the use of negative elevation values. As the crater Aristarchus was found to be the lowest feature in the control system, 7.0 kilometers lower than Mosting A, it was assigned an elevation of zero, making the elevation of the vertical datum 7000 meters.

These maps were compiled with an M-2 stereoplotter which was substantially modified to accommodate the special characteristics of the lunar photography. The principal modification was an increase in the projection distance of the plotter from 2-1/2 to 10 feet. The compilation was performed for 288 individual 10°x10° segments which were then rectified and joined to form the compilation of the entire lunar earthside. This compilation, at 3,300,000 scale, was the basis for all three map series listed above.

Area coverage of these maps is shown in Map Index I(4).

4.1.8 APOLLO ZONE PRIMARY SITES MOSAIC
(Published by USATOPOCOM)

Apollo Zone Primary Sites
1st Edition 1968
Scale: 1:2,500,000 (approximately)
Projection: Mercator
Limits 8°N 8°S (approx) 52°E 52°W (approx)
Sheet Size: 11" x 53"

This controlled photomosaic provides limited coverage of the lunar equatorial zone using Orbiter IV photographs and showing the five primary Apollo landing sites initially defined by the Manned Spacecraft Center (MSC). This photomosaic was produced with no overprint names or border notes.

4.2 MEDIUM SCALE MAPS, PHOTOMAPS AND PHOTO MOSAICS
(1:250,001 - 1:1,999,999)

Lunar Astronautical Chart Series (LAC) 4.2.1

Apollo Intermediate Chart Series (AIC) 4.2.2

Ranger Lunar Charts 4.2.3

4.2.1 LUNAR ASTRONAUTICAL CHART (LAC) SERIES
(Published by ACIC)

Lunar Astronautical Charts
Scale: 1:1,000,000
Projection: Mercator and Lambert Conformal Conic
Sheet Size: 22" x 29"

The LAC sheet layout which has often been used as a location reference in other lunar maps and publications provides for complete lunar coverage through 144 sheets. Forty-two nearside sheets have actually been published using earthbased telescopic photography and visual observations as basic sources.

The charts are constructed on a Mercator projection (true scale at 11°00'45") for charts in bands 0° to 16°N and 0° to 16°S; and, on a Lambert conformal conic projection in the following bands:

16°N-S to 32°N-S (standard parallels 21°20' and 42°40')

32°N-S to 48°N-S (standard parallels 21°20' and 42°40')

48°N-S to 80°N-S (standard parallels 53°20' and 74°40')

The ACIC Selenodetic System (1965) was under development during the production of the LAC Series and later date sheets used this System for control. However, sheets in production at earlier dates primarily relied on selenographic control established from the measures of J. Franz and S. A. Saunder as compiled by D. W. G. Arthur and E. A Whitaker in the Orthographic Atlas of the Moon. Gradients of major surface undulations were established by interpolating Schrutka-Rechtenstamm computations of J. Franz's measurements of 150 moon craters. The varying control sources used during the course of compilation have sometimes resulted in mismatch of contour information between adjacent sheets.

LAC charts portray lunar topography by shadient relief with a western illumination, approximate contours (300 meter interval), spot elevations, height differences between level features and crater depths. Background coloration is also used to indicate variance in reflectance of lunar areas under full illumination. Contours are omitted from many sheets (generally those covering limb areas) and the reverse side of some sheets contains a printing of the shadient relief portrayal, unencumbered with other chart detail.

Chart margin information includes an index of the series and qualifying and explanatory statements on the control, datum, nomenclature, relief portrayal and elevation data contained.

Feature names were taken from the International Astronomical Union nomenclature system. A dashed limiting line or dotted line is used to identify some features.

The LAC series was the principal source of available lunar cartographic information prior to the production of lunar maps from orbital photography. Its compilation included derivation of accurate local feature heights and depths through measurement of shadow images on source photography. However, use of earthbased vertical control and photography have not allowed definition of reliable regional elevation differences. By virtue of its scale, extent of coverage and topographic information contained, the LAC series continues to be of cartographic importance.

The area of coverage provided by individual LAC sheets is reflected in Map Index I(5).

CHART NO.	CHART NAME	EDITION & DATE
LAC-11	J. Herschel	1st Ed. Mar 1967
LAC-12	Plato	1st Ed. Jan 1967
LAC-13	Aristoteles	1st Ed. Jul 1967
LAC-23	Rumker	1st Ed. Feb 1967
LAC-24	Sinus Iridum	1st Ed. Sep 1966
LAC-25	Cassini	1st Ed. Sep 1966
LAC-26	Eudoxus	1st Ed. Mar 1967
LAC-27	Geminus	1st Ed. Jul 1967
LAC-38	Seleucus	1st Ed. Mar 1965
LAC-39	Aristarchus	1st Ed. Nov 1963
LAC-40	Timocharis	1st Ed. Oct 1963
LAC-41	Montes Apenninus	1st Ed. Sep 1963
LAC-42	Mare Serenitatis	1st Ed. Feb 1965

CHART NO.	CHART NAME	EDITION & DATE
LAC-43	Macrobius	1st Ed. May 1965
LAC-44	Cleomedes	1st Ed. Dec 1965
LAC-56	Hevelius	1st Ed. May 1963
LAC-57	Kepler	2nd Ed. May 1962
LAC-58	Copernicus	2nd Ed. Apr 1964
LAC-59	Mare Vaporum	2nd Ed. Aug 1966
LAC-60	Julius Caesar	1st Ed. Sep 1962
LAC-61	Taruntius	1st Ed. Feb 1963
LAC-62	Mare Undarum	1st Ed. Feb 1964
LAC-74	Grimaldi	1st Ed. Apr 1962
LAC-75	Letronne	2nd Ed. Jun 1962
LAC-76	Montes Riphaeus	2nd Ed. Apr 1964
LAC-77	Ptolemaeus	1st Ed. May 1963
LAC-78	Theophilus	1st Ed. Mar 1963
LAC-79	Colombo	1st Ed. Apr 1963
LAC-80	Langrenus	1st Ed. [illegible] 1964
LAC-92	Byrgius	1st [illegible] Feb 1966
LAC-93	Mare Humorum	1st Ed. [illegible] 1962
LAC-94	Pitatus	[illegible]
LAC-95	Purbach	1st Ed. [illegible] 1964
LAC-96	Rupes Altai	1st Ed. Apr 1965

CHART NO.	CHART NAME	EDITION & DATE
LAC-97	Fracastorius	1st Ed. May 1965
LAC-98	Petavius	1st Ed. May 1966
LAC-110	Schickard	1st Ed. Sep 1967
LAC-111	Wilhelm	1st Ed. Oct 1967
LAC-112	Tycho	1st Ed. Jul 1967
LAC-113	Maurolycus	1st Ed. Dec 1966
LAC-114	Rheita	1st Ed. Oct 1966
LAC-125	Schiller	1st Ed. Oct 1967
LAC-126	Clavius	1st Ed. Oct 1967
LAC-127	Hommel	1st Ed. Nov 1967

4.2.2 APOLLO INTERMEDIATE CHART (AIC) SERIES
(Published by ACIC)

Apollo Intermediate Charts
Scale: 1:500,000
Projection: Mercator
Sheet Size: 22" x 29"

The Apollo Intermediate Chart Series (AIC) was produced to support early planning in the primary portion of the Apollo Zone of interest.

This series was constructed on a Mercator projection with true scale at 11.0125° North and South latitude. Its area of coverage is from 0° to 8° north and south latitude and 50° east to 50° west longitude. The twenty charts which comprise the AIC series were published between August 1965 and January 1967.

Feature positions and elevations shown on these charts are based on the ACIC Selenodetic System (1965). To support chart compilation at this scale, supplementary positional data was developed in each chart area.

The charts were developed from earth-based telescopic photographs which were rectified and mosaicked to fit the horizontal control network. Photographic details were supplemented by visual telescopic observations accomplished at Lowell Observatory in Flagstaff, Arizona.

The shaded relief drawing contained was developed using an assumed light source from the west to portray relief features as they would appear when the angle of illumination is equal to the angle of slope. This resulted in a drawing which simulates the lighting conditions on the lunar landscape under the evening terminator, but without shadows. Also, a background coloration drawing was prepared to supplement the scheduled relief portrayal. This drawing depicts the variaties in reflectance of the lunar surface under full moon illumination. The two drawings were lithographed with the relief in green and the background coloration in light blue.

Definition of relief includes lunar radius vectors of selected features and their estimated reliability. Relative heights and crater depths determined by shadow measuring techniques are also shown.

Feature names were taken from the International Astronomic Union nomenclature system. As necessary, a dotted or dashed limiting line was used to positively identify the exact feature.

The shaded relief is also printed on the reverse side of these charts. All overprinting information was omitted to provide the user an unobstructed view of the interpreted lunar surface detail. Selected areas of interest on the reverse side printing are outlined and described in the margin with respect to the observed appearance without an intended inference as to the origin and development of the lunar surface.

Chart margin information includes chart title, general notes, bar scale reliability diagrams and a sheet index referenced to the LAC series. Within the border notes are statements on the control, datum, nomenclature, relief portrayal and elevation data. Extent of coverage of individual AIC charts is shown in Map Index I(5).

CHART NO.	NAME	EDITION AND DATE
AIC 57C	Encke	1st Ed Aug 1966
AIC 57D	Maestlin	1st Ed Aug 1966
AIC 58C	Gambart	1st Ed May 1965 2nd Ed Aug 1966
AIC 58D	Reinhold	1st Ed Mar 1965 2nd Ed Aug 1966
AIC 59C	Triesnecker	1st Ed Jan 1966
AIC 59D	Pallas	1st Ed Jan 1966
AIC 60C	Arago	1st Ed Mar 1966
AIC 60D	Agrippa	1st Ed May 1965 2nd Ed Aug 1966
AIC 61C	Secchi	1st Ed Jan 1967
AIC 61D	Maskelyne D	1st Ed May 1966
AIC 75A	Flamsteed	1st Ed Aug 1966
AIC 75B	Wichmann	1st Ed Aug 1966
AIC 76A	Euclides P	1st Ed Jun 1966
AIC 76B	Fra Mauro	1st Ed Jun 1966
AIC 77A	Flammarion	1st Ed May 1965 2nd Ed Sep 1966
AIC 77B	Hipparchus	1st Ed Mar 1966

CHART NO.	NAME	EDITION AND DATE
AIC 78A	Delambre	1st Ed Mar 1966
AIC 78B	Torricelli	1st Ed Apr 1966
AIC 79A	Capella	1st Ed Jun 1966
AIC 79B	Messier	1st Ed Dec 1966

4.2.3 RANGER LUNAR CHARTS

Ranger Lunar Charts were produced by ACIC during 1964-1965 using photography acquired on Ranger Missions VII, VIII, IX. Individual charts were produced at scales ranging from 1:400 - 1:1,000,000 on a Mercator projection with the scale at 11°00'45"S. A sheet size of 22" x 29" was used except for Chart RLC-2 which is 29" x 31". Details of large scale sheets are provided in Section 4.3.3.

These products were compiled from photographs recorded from the Ranger Television Camera systems (both narrow and wide angle fields) before impacting the lunar surface. The various publication scales were selected to most completely portray imagery contained in the available photography. Extensive photo rectification was required to size the photographs to the selected scales and control. All of the sheets of this series are based on the ACIC Selenodetic System (1965).

Relief is expressed by shadient portrayal, spot elevations and crater depth values. The relief is produced by a duotone printing using black and green inks. Each sheet contains a black overprint of projection, lunar nomenclature, crater depths and spot elevations. A red overprint is used to show the spacecrafts trajectory trace, each camera track, photo coverage and the outline of the succeeding chart plus the impact point. A black printing, void of overprint information, is also available to give the user an unobstructed view of the lunar surface detail depicted by the shaded relief drawing.

Feature names are taken from the IAU's accepted list. Supplementary features are associated with the named features through the addition of identifying letters.

Chart margin information includes chart location, diagram, and general notes and statements on the control system used, lunar nomenclature, elevation data, and relief portrayal.

RANGER VII LUNAR CHARTS
1st Edition October 1964

CHART	EXTENT OF COVERAGE PER SHEET
RLC-1 Mare Cognitum Scale 1:1,000,000	10°W to 30°W 0° to 16°S
RLC-2 Guericke Scale 1:500,000	13°W to 16°W 8°S to 16°S

RANGER VIII LUNAR CHARTS
1st Edition March 1966

CHART	EXTENT OF COVERAGE PER SHEET
RLC-6 Hypatia Scale 1:1,000,000	10°E to 30°E 4°N to 12°S

RANGER IX LUNAR CHARTS
1st Edition May 1966

CHART	EXTENT OF COVERAGE PER SHEET
RLC-13 Ptolemaeus Scale 1:1,000,000	10°W to 10°E 0° to 16°S

4.3 LARGE SCALE MAPS, PHOTOMAPS AND PHOTOMOSAICS (1:250,000 and Larger Scale)

Production of valid large scale lunar maps became possible with the availability of spacecraft photography at scales allowing detailed description of lunar features and other sensor data which provided a basis for control point determination. The maps have been produced to enable study of potential lunar landing sites and areas of scientific interest.

The following large scale map series describe the lunar surface through rectified photographic imagery, contour information, shadient relief (artistic representation) and orthophotographic imagery. The Lunar Topographic Orthophotomap and Lunar Orthophotomap Series are generally preferred within their scale range and area of coverage. These sheets eliminate positional inaccuracies due to relief displacement occurring in map bases prepared from conventional perspective photographs while retaining the advantages of completeness of detail provided by photographs.

Photomap & Lunar Map Series (ORB) 4.3.1

Lunar Photomap, Topographic Photomap, and Topographic Map Series 4.3.2

Ranger Lunar Charts 4.3.3

Surveyor Lunar Photomap & Map Series 4.3.4

Lunar Topographic Orthophotomap & Lunar Orthophotomap Series 4.3.5

Other Maps, Photomaps & Mosaics 4.3.6

4.3.1 LUNAR PHOTOMAP AND MAP SERIES (ORB)

These lunar site maps were produced in Photomap and Lunar Map form by ACIC and TOPOCOM in 1967 and 1968 to support study of potential Apollo landing sites. The sheets are identified by the designators ORB followed by site numbers and an abbreviated statement of scale in parentheses. For example: a 1:100,000 scale map of Lunar Orbiter I, site 5, is designated ORB I-5 (100). The maps were produced at 1:100,000 and 1:25,000 scales to provide photomosaic and topographic map coverage of these sites. The 1:100,000 scale sheets used medium resolution Lunar Orbiter Mission photographs; 1:25,000 scale sheets used high resolution photographs, and generally were produced only in photomap form. A black overprint of the projection and feature names appears on all maps of this series. The nomenclature is selected from the International Astronomical Union's accepted list.

Vertical and horizontal positions are based on local lunar control systems which employed analytical photogrammetric triangulation with Lunar Orbiter Mission Site Photography and Photo Support Data.

Map margin information contains a site index referenced to LAC and AIC chart series. Area coverage of 1:100,000 and 1:25,000 scale sheets are shown on Map Indices I(7) and I(8) respectively.

The photomap sheets only reflect photographic detail and are lithographed in black. The map sheets show hypsography by shadient relief, contours, spot elevations, height of rim elevations above surrounding terrain, and crater depths. Contour values and spot elevations are shown as lunar radius vectors expressed in meters. The basic contour interval is 100 meters with 50 meter supplements. Contour information is lacking in areas not having stereoscopic photographic coverage. Horizontal and vertical reliability information is expressed in the map margin. The map base is a green and black duotone printing with relief values overprinted in black and contours in red. In some instances where stereoscopic coverage is lacking, the lunar surface area portrayed on the Lunar Maps has been reduced from that shown on the Photomaps.

Published sheets were developed from a 1:100,000 photomosaic base which was produced by rectification and assembly of medium resolution Lunar Orbiter photographs to control points. This base was enlarged to 1:25,000 and used to control the rectification and assembly of the high resolution photographs. Reproduction of the final 1:25,000 and 1:100,000 mosaics with described overprints resulted in the Photomap series sheets.

In ACIC's early Lunar Map productions from Lunar Orbiter I materials, positions of delineated features were taken directly from the 1:100,000 base mosaics. In Orbiter II and III based products, the base mosaics and Orbiter photographs were also used for the delineation of Map series features, with readjustments to control point positions before addition of shadient relief by airbrush technique. Contour information was developed by interpolating between the control points developed from analytical photogrammetric triangulation.

TOPOCOM employed stereoplotting equipment to compile feature positions and contour information for Lunar Map manuscripts. However, the segmented framelet form of Orbiter photography prevented continuous compilation within each photo frame, requiring adjustment of individual framelet model compilations to each other.

The principal value of this series is in the lunar surface details shown and the relative positions and elevations expressed for area features. The horizontal and vertical datums of sheets of this series are based on early Control Systems which are subject to the systematic errors contained in preliminary Photo Support Data.

Orbiter I - Site 1 (ORB I-1) 4.3.1.1

Orbiter I - Site 2 (ORB I-2) 4.3.1.2

Orbiter I - Site 3 (ORB I-3) 4.3.1.3

Orbiter I - Site 4A&B (ORB I-4A,B) 4.3.1.4

Orbiter I - Site 5 (ORB I-5) 4.3.1.5

Orbiter I - Site 7 (ORB-7) 4.3.1.6

Orbiter I - Site 8 (ORB-8) 4.3.1.7

Orbiter I - Site 9.2 (ORB-9.2) 4.3.1.8

Orbiter II - Site 2 (ORB II-2) 4.3.1.9

Orbiter II - Site 6 (ORB II-6) 4.3.1.10

Orbiter II - Site 8 (ORB II-8) 4.3.1.11

Orbiter II - Site 11 (ORB II-11) 4.3.1.12

Orbiter II - Site 13 (ORB II-13) 4.3.1.13

Orbiter III - Site 9 (ORB III-9) 4.3.1.14

Orbiter III - Site 11 (ORB III-11) 4.3.1.15

Orbiter III - Site 12 (ORB III-12) 4.3.1.16

4.3.1.1 ORBITER I - SITE 1 (ORB I-1)
(Published by TOPOCOM)

Lunar Photomap	Lunar Map
1st Edition June 1967	1st Edition September 1967
Scale: 1:100,000	Scale: 1:100,000
Projection: Mercator	Projection: Mercator
Sheet Size: 21.5" x 44"	Sheet Size: 21.5" x 41"

The extent of coverage of the Lunar Photomap (standard parallels at 2°30' N-S) is 0°12'S to 1°48'S and 40°00'E to 43°48'E. The Lunar Map (same standard parallels) provides coverage from 0°12'S to 1°48'S and 40°12'E to 43°00'E.

These products were compiled from Lunar Orbiter Mission I medium-resolution frames 52-67 and are based on Control System I-1 (1967) described in Section 3.3.1.1, which clarifies use of Department of Defense (DOD) control noted in Photomap margin. The 202 meter horizontal and 529 meter vertical accuracy statements appearing in the Lunar Map margin apply to control used rather than overall map accuracy.

Photomap use is limited by poor quality of photo imagery shown in western portion. This has also contributed to the lesser vertical accuracy achieved in the Lunar Map where use of contours is limited to definition of large elevation changes.

4.3.1.2 ORBITER I SITE 2 (ORB I-2)
(Published by TOPOCOM)

Lunar Photomap
1st Edition June 1967
Scale: 1:100,000
Projection: Mercator
Sheet Size: 21.5" x 44"

Lunar Map
1st Edition September 1967
Scale: 1:100,000
Projection: Mercator
Sheet Size: 21.5" x 41"

The extent of coverage for the Lunar Photomap (standard parallels at 2°30'N-S) is 1°00'N to 0°48'S and 34°00'E to 37°00'E. The Lunar Map (Same standard parallels) provides coverage from 1°00'N to 0°48'S and 33°48'E to 37°12'E.

These products were compiled from Lunar Orbiter Mission I medium resolution frames 68-71, 74, 77, 80-83 and are based on Control System I-2 (1967) described in Section 3.3.1.2. The 142 meter horizontal accuracy and 200 to 600 meter vertical accuracy statements appearing in the Lunar Map margin apply to control used rather than overall map accuracy. The 200 meter vertical accuracy applies to the central portion of the chart.

4.3.1.3 ORBITER I SITE 3 (ORB I-3)
(Published by TOPOCOM)

Lunar Photomap	Lunar Map
1st Edition April 1967	1st Edition May 1967
Scale: 1:100,000	Scale: 1:100,000
Projection: Mercator	Projection: Mercator
Sheet Size: 20.5" x 44"	Sheet Size: 21" x 40.5"

The extent of coverage for the Lunar Photomap (standard parallels at 2°30'N-S) is 1°36'N to 0°24'S and 24°24'E to 28°00'E. The Lunar Map (same standard parallels) provides coverage from 1°36'N to 0°24'S and 26°24'E to 27°48'E.

These products were compiled from Lunar Orbiter Mission I medium resolution frames 85-88, 91, 94, 97-100 and are based on Control System I-3 (1967) described in Section 3.3.1.3. Photomap margin data indicates product is based on DOD (1966) Selenodetic Control System. However, nature of control development did not effect this relation as discussed in referenced Control Section. Lunar map margin data states relative absolute error factors and relationship to DOD 1966 control system. The stated 44 meter horizontal and 160 meter vertical relative errors apply to relation of nearby control points. The 338 meter horizontal and 605 meter vertical error statements are intended to apply to relationship of points throughout the chart area. These error quantities apply to the control points used rather than actual map accuracy.

4.3.1.4 ORBITER I SITE 4A, B (ORB I-4A, B)
(Published by TOPOCOM)

Lunar Photomap A and B
1st Edition February 1968
Scale: 1:100,000
Projection: Mercator
Number of Sheets: 2
Sheet Size: 19" x 25.5"

Lunar Map A and B
1st Edition May 1968
Scale: 1:100,000
Projection: Mercator
Number of Sheets: 2
Sheet Size: 19" x 25.5"

The extent of coverage for the Lunar Photomap and Lunar Map (standard parallels at 2°30'N-S) is 0°36'N to 0°36'S and 11°24'E to 15°36'E.

These products were compiled from Lunar Orbiter Mission I medium resolution frames 105-112 and are based on Control System I-4 (1967) described in Section 3.3.1.4. The 99 meter horizontal accuracy and 100 to 250 meter vertical accuracy statements appearing in the Lunar Map margin apply to control used rather than overall map accuracy.

4.3.1.5 ORBITER I SITE 5 (ORB I-5)
(Published by ACIC)

Lunar Photomap	Lunar Map
1st Edition March 1967	1st Edition March 1967
Scale: 1:100,000	Scale: 1:100,000
Sheet Size: 19" x 40"	Sheet Size: 19" x 40"

The extent of coverage for the Lunar Photomap (standard parallels at 2°34'N-S) is 1°N to 0°48'S and 0°12'E to 3°12'W. The Lunar Map (same standard parallels) provides coverage from 0°52'N to 0°46'S and 0°12'W to 2°46'W.

These products were compiled from Lunar Orbiter Mission I medium resolution frames 118-133 and are based on Control System I-5 (1967) described in Section 3.3.1.5. Photomap margin data characterizes this control system as an extension of the DOD Selenodetic System (1966) and three of the earthbased system control points are symbolized on these maps.

Contour information appearing on the Lunar Map is limited and the 25 meter relative vertical accuracy stated in chart margin is considered overly optimistic. Relative vertical accuracy is estimated to approximate ± 150 meters at 90% probability and the horizontal accuracy of these sheets with respect to the I-5 (1967) Datum is estimated at 500 meters (90% probability).

4.3.1.6 ORBITER I SITE 7 (ORB I-7)
(Published by TOPOCOM)

Lunar Photomap
1st Edition June 1967
Scale: 1:100,000
Sheet Size: 20" x 40"
Projection: Mercator

Lunar Map
1st Edition September 1967
Scale: 1:100,000
Sheet Size: 20" x 37"
Projection: Mercator

The extent of coverage for the Lunar Photomap (standard parallels at 2°30'N-S) is 2°36'S to 4°24'S and 20°24'W to 23°48'W. The Lunar Map (same standard parallels) provides coverage from 2°36'S to 4°24'S and 20°36'W to 23°36'W.

These products were compiled from Lunar Orbiter Mission I medium resolution frames 157-160, 163, 166, 169-172 and are based on Control System I-7 (1967) described in Section 3.3.1.6, which clarifies use of DOD control noted in Photomap margin. The 202 meter horizontal and 513 meter vertical accuracy statements appearing in the Lunar Map margin apply to control used rather than overall map accuracy. Accuracy of contour information is inadequate for definition of elevation differences in this area.

4.3.1.7 ORBITER I SITE 8 (ORB I-8)
(Published by TOPOCOM)

Lunar Photomap
1st Edition June 1967
Scale: 1:100,000
Projection: Mercator
Sheet Size: 20" x 27.5"

Lunar Map
1st Edition July 1967
Scale: 1:100,000
Projection: Mercator
Sheet Size: 20" x 24.5"

The extent of coverage for the Lunar Photomap (standard parallels at 2°30'N-S) is 2°12'S to 3°48'S and 35°24'W to 37°48'W. The Lunar Map (same standard parallels) provides coverage from 2°12'S to 3°48'S and 35°36'W to 37°36'W.

These products were compiled from Lunar Orbiter Mission I medium resolution frames 176-183 and based on Control System I-8 (1967) described in Section 3.3.1.7 which clarifies use of DOD control notes in the map margins. Two printings of the map express varying accuracy evaluation criteria. The map accuracy is unevaluated.

4.3.1.8 ORBITER I SITE 9.2 (ORB I-9.2)
(Published by ACIC)

Lunar Photomap
1st Edition March 1967
Scale: 1:100,000
Projection: Mercator
Sheet Size: 24" x 40"

Lunar Photomaps A-H
1st Edition March 1967
Scale: 1:25,000
Projection: Mercator
Number of Sheets: 8
Sheet Size: 23" x 30"

Lunar Map
1st Edition April 1967
Scale: 1:100,000
Projection: Mercator
Sheet Size: 24" x 40"

Lunar Maps A-H
1st Edition May 1967
Scale: 1:25,000
Projection: Mercator
Number of Sheets: 8
Sheet Size: 23" x 30"

The extent of coverage for the 1:100,000 scale sheets (standard parallels of 2°30'N-S) is 1°7'S to 3°26'S and 41°36'W to 45°W. The 1:25,000 scale sheets (same standard parallels) provides coverage from 1°36'S to 2°58'S and 41°58'W to 44°32'W. Map sheet contours are restricted to portrayal of outstanding features and prominences and have an evaluated local accuracy of ± 25 meters. A 25 meter contour interval was used for the 1:25,000 scale maps. The 1:25,000 photomap sheets have poor definition of photographic detail due to excessive enlargement required to bring Orbiter Mission I medium resolution photography to publication scale.

The 1:100,000 and 1:25,000 scale products were compiled from Lunar Orbiter Mission 1 medium resolution frames 184-215. They are based on Control System I-9 (1967) described in Section 3.3.1.8.

4.3.1.9 ORBITER II SITE 2 (ORB II-2)
(Published by TOPOCOM)

Lunar Photomap
1st Edition September 1967
Scale: 1:100,000
Projection: Mercator
Sheet Size: 24.5" x 18"

Lunar Map
1st Edition December 1967
Scale: 1:100,000
Projection: Mercator
Sheet Size: 21.5" x 19"

Lunar Photomap
1st Edition November 1967
Scale: 1:25,000
Projection: Mercator
Sheet Size: 29" x 50"

The extent of coverage for the 1:100,000 scale sheets (standard parallels of 2°30'N-S) is 1°55'N to 3°26'N and 33°E to 35°E. The 1:25,000 scale map (same standard parallels) provides coverage from 2°20'N to 3°3'N and 33°28'E to 34°32'45"E.

The 1:100,000 and 1:25,000 products were compiled from Lunar Orbiter Mission II medium and high resolution frames 35-42. They are based on Control System II-2 (1967) described in Section 3.3.1.9 which clarifies the use of DOD control noted in the Photomap margin. The 66 meter horizontal and 100 to 150 meter vertical accuracy statements in the Lunar Map margin apply to control used rather than overall map accuracy.

4.3.1.10 ORBITER II SITE 6 (ORB II-6)
(Published by TOPOCOM)

Lunar Photomap
1st Edition October 1967
Scale: 1:100,000
Projection: Mercator
Sheet Size: 24.5" x 26"

Lunar Map
1st Edition December 1967
Scale: 1:100,000
Projection: Mercator
Sheet Size: 23" x 24"

Lunar Photomaps A-D
1st Edition November 1967
Scale: 1:25,000
Projection: Mercator
Number of Sheets: 4
Sheet Size: 28.5" x 27.5"

The extent of coverage from the 1:100,000 scale sheets (standard parallels of 2°30'N-S) is 0°08'S to 1°54'N and 22°57'E to 25°15'E. The 1:25,000 scale map (same standard parallels) provides coverage from 0°18'N to 1°30'N and 23°26'E to 24°44'E.

The 1:100,000 and 1:25,000 scale products were compiled from Lunar Orbiter Mission II medium and high resolution frames 76-91. They are based on Control System II-6 (1967) described in Section 3.3.1.10 which clarifies use of DOD control noted in the Photomap margin. The 88 meter horizontal and 262 meter vertical accuracy statements appearing in the Lunar margin apply to control used rather than overall map accuracy. Data was added to the Lunar Map from Lunar Orbiter Missions I and III photographs.

4.3.11 ORBITER II SITE 8 (ORB II-8)
(Published by ACIC)

Lunar Photomap
1st Edition August 1967
Scale: 1:100,000
Projection: Mercator
Sheet Size: 27" x 27.5"

Lunar Map
1st Edition December 1967
Scale: 1:100,000
Projection: Mercator
Sheet Size: 25.5" x 28"

Lunar Photomaps A-D
1st Edition October 1967
Scale: 1:25,000
Projection: Mercator
Number of Sheets: 4
Sheet Size: 30.5" x 36.5"

Lunar Maps A-D
1st Edition February 1968
Scale: 1:25,000
Projection: Mercator
Number of Sheets: 4
Sheet Size: 31" x 36"

The extent of coverage for the 1:100,000 scale sheets (standard parallels at 2°30'N-S is 1°24'N to 0°36'S and 0°12'E to 2°12'W. The 1:25,000 scale sheets (same standard parallels) provides coverage from 1°N to 0°32'S and 0°18'W to 1°48'W.

The 1:100,000 and 1:25,000 scale products were compiled from Lunar Orbiter Mission II medium and high resolution frames 113-136. They were supplemented by Orbiter Mission I medium resolution exposures 118-133 and Mission III exposures 86-101. The maps are based on control system II-8 (1967) described in Section 3.3.1.11. The 1:25,000 scale maps have shadient relief portrayal and show a 25 meter contour interval with an evaluated vertical accuracy of 100 meters at 90% probability. The 1:100,000 scale map has an evaluated vertical accuracy of 300-800 meters (90% probability). The evaluated horizontal accuracy for all sheets of this group is 66 meters expressed at 90% probability.

With the exception of elevation differences between local features, contour information shown on these sheets is considered unreliable.

4.3.1.12 ORBITER II SITE 11 (ORB II-11)
(Published by TOPOCOM)

Lunar Photomap
1st Edition November 1967
Scale: 1:100,000
Projection: Mercator
Sheet Size: 26" x 30"

Lunar Map
1st Edition February 1968
Scale: 1:100,000
Projection: Mercator
Sheet Size: 26" x 26.5"

Lunar Photomaps A-D
1st Edition November 1967
Scale: 1:25,000
Projection: Mercator
Number of Sheets: 4
Sheet Size: 28" x 33"

The extent of coverage for the 1:100,000 scale sheets (standard parallels at 2°30'N-S) is 0°57'N to 1°18'S and 18°36'W to 20°54'W. The 1:25,000 scale sheets (same standard parallels) provides coverage from 0°30' N to 0°47'S and from 18°59'W to 20°20'W. The 1:100,000 photomap is devoid of photo coverage in the area north of 0°12'S and east of 18°30'W. Sheet II-11B is devoid of photo coverage in the area south of 0°6'S and west of 20°20'W.

The 1:100,000 and 1:25,000 scale products were compiled from Lunar Orbiter Mission II medium and high resolution frames 163-167, 169-178, and 171-178. They are based on Control System II-11 (1967) described in Section 3.3.1.12, which clarifies use of DOD control notes in the Photomap margin. The 62 meter horizontal and 130 to 180 meter vertical accuracy statements appearing in the Lunar Map margin apply to control used rather than overall map accuracy.

4.3.1.13 ORBITER II SITE 13 (ORB II-13)
(Published by TOPOCOM)

Lunar Photomap
1st Edition November 1967
Scale: 1:100,000
Projection: Mercator
Sheet Size: 23" x 27"

Lunar Map
1st Edition December 1967
Scale: 1:100,000
Projection: Mercator
Sheet Size: 24" x 24"

Lunar Photomaps A-D
1st Edition November 1967
Scale: 1:25,000
Projection: Mercator
Number of Sheets: 4
Sheet Size: 26.5" x 29.5"

The extent of coverage for the 1:100,000 scale sheets (standard parallels at 2°30'N-S) is 0°43'N to 2°40'N and 40°36'W to 42°48'W. The 1:25,000 scale sheets (same standard parellels) provides coverage from 1°7'N to 2°17'N and 41°8'W to 42°19'W. The 1:100,000 scale photomap is devoid of photo coverage in small areas in the northeast and southwest corners of the sheet. Sheet II-13A is devoid of photo coverage in a small area along the eastern portion of the north margin. Sheet II-13B is devoid of photo coverage in the area east of 41°12'W and north of 1°40'N. Sheet II-13D is devoid of photo coverage in an area south of 1°43'N and west of 42°15'W.

The 1:100,000 and 1:25,000 scale products were compiled from Lunar Orbiter Mission II medium and nigh resolution frames 197-212. They are based on control system II-13 (1967) described in Section 3.3.1.13 which clarifies use of DOD control noted in the Photomap margin. The II-13 (1967) control system is based on ephemeral data from Lunar Orbiter Mission II, and not from Lunar Orbiter Mission I, as stated in the Lunar Map margin. The 85 meter horizontal (90% probability) and 190 to 225 meter vertical (90% probability) accuracies apply to control used rather than overall map accuracy.

4.3.1.14 ORBITER III SITE 9 (ORB III-9)
(Published by TOPOCOM)

Lunar Photomap
1st Edition January 1968
Scale: 1:100,000
Projection: Mercator
Sheet Size: 23.5" x 26"

Lunar Map
1st Edition March 1968
Scale: 1:100,000
Projection: Mercator
Sheet Size: 24" x 26"

Lunar Photomaps A-D
1st Edition February 1968
Scale: 1:25,000
Projection: Mercator
Number of Sheets: 4
Sheet Size: 27" x 34"

The extent of coverage for the 1:100,000 scale sheets (standard parallels 2°30'N-S) is 1°54"S to 4°03'S and 21°44'W to 24°08'W. The 1:25,000 scale sheets (same standard parallels) provide coverage from 2°21'S to 3°24'S and 22°07'W to 23°44'W. The 1:100,000 scale sheets are void of detail in small areas of the northwest and southeast corners. Sheet III-9A is void of photo coverage in the area west of 23°17'W and north of 2°38'S. Sheet III-9C is void of photo coverage in the area east of 22°38'W and south of 3°16'S.

These products were compiled from Lunar Orbiter Mission III medium and high resolution frames 145-160. They are based on Control System III-9 (1967) described in Section 3.3.1.16. The 58 meter horizontal and 100 to 300 meter vertical accuracy statements appearing in the Lunar Map margin apply to control used rather than overall map accuracy.

4.3.1.15 ORBITER III SITE 11 (ORB III-11)
(Published by TOPOCOM)

Lunar Photomap
1st Edition January 1968
Scale: 1:100,000
Projection: Mercator
Sheet Size: 23" x 26"

Lunar Map
1st Edition February 1968
Scale: 1:100,000
Projection: Mercator
Sheet Size: 21.5" x 25"

Lunar Photomaps A and B
1st Edition January 1968
Scale: 1:25,000
Projection: Mercator
Number of Sheets: 2
Sheet Size: 29" x 34"

The extent of coverage for the 1:100,000 scale sheets (standard parallels 2°30'N-S) is 2°24'S to 4°26'S and 35°42'W to 38°00'W. The 1:25,000 scale sheets (same standard parallels) provide coverage from 2°53'S to 3°54'S and 36°10'W to 37°30'W.

These products were compiled from Lunar Orbiter Mission III medium to high resolution frames 173-180. They are based on Control System III-11 (1967) described in Section 3.3.1.18. The 72 meter horizontal accuracy and 100 to 300 meter vertical accuracy statements appearing in the Lunar Map margin apply to control used rather than overall map accuracy.

4.3.1.16 ORBITER III SITE 12 (ORB III-12)
(Published by ACIC)

Lunar Photomap
1st Edition January 1968
Scale: 1:100,000
Projection: Mercator
Sheet Size: 36" x 47"

Lunar Map
1st Edition March 1968
Scale: 1:100,000
Projection: Mercator
Sheet Size: 36" x 47"

Lunar Photomaps A-I
1st Edition June 1968
Scale: 1:25,000
Projection: Mercator
Number of Sheets: 9
Sheet Size: 29" x 42"

The extent of coverage for the 1:100,000 scale sheets (standard parallels 2°30'N-S) is 0°36'S to 4°12'S and 41°48'W to 45°36'W. The 1:25,000 scale sheets (same standard parallels) provide coverage from 1°36'S to 3°38'S and 42°26'W to 45°02'W.

These products were compiled from Lunar Orbiter Mission III medium and high resolution frames 118-133. The 1:100,000 Lunar Photomap is based on the horizontal datum defined by the III-P-12 Control System (1967) described in Section 3.3.1.19. The 1:25,000 Lunar Photomaps were constructed by assembly of rectified high resolution photography to the positions defined by the smaller scale photomap.

The Lunar Map is based on the III-12 (1968) System with a horizontal accuracy of 150 meters and a vertical accuracy of 30 to 100 meters (90% probability). Area variations in vertical accuracy are shown by diagram in map margin. In map construction features were originally positioned with respect to the 1967 Control System followed by a graticule shift to bring the compilation into general agreement with the 1968 Control System.

The Lunar Photomap sheets may be used to study the detailed lunar features; the Lunar Maps are recommended to satisfy requirements for positions and elevations.

4.3.2 LUNAR PHOTOMAP, TOPOGRAPHIC PHOTOMAP AND TOPOGRAPHIC MAP SERIES

These lunar scientific site maps were produced as Photomaps, Topographic Photomaps and Topographic Maps by ACIC and TOPOCOM. Publication of individual sheets began in May 1969 to provide a basis for study of lunar sites of scientific interest. Each sheet is identified by the name of the lunar feature or area of prime interest within its limits. Maps were produced at a scale of 1:250,000 using Lunar Orbiter Mission III and V medium resolution photographs as basic source material. The 1:25,000 scale products used high resolution photographs and were produced only as photomaps. A black overprint of the projection and feature names appears on all sheets of this series. The nomenclature is selected from the International Astronomical Union's accepted list.

Vertical and horizontal positions are based on local lunar control systems which employed analytical photogrammetric triangulation with Lunar Orbiter Mission site photography and Photo Support Data.

Map margin information contains a site index referenced to a Lunar Astronomical Chart (LAC), vertical and horizontal reliability information and a diagram depicting the sun angle of the photographs used.

Sheets show photomosaic detail and are lithographed in black. Topographic Photomap sheets show photomosaic detail, overprinted by contours in red with spot elevations expressed as lunar radius vectors in meters. The Topographic Map sheets express relief by shadient portrayal. Contours and spot elevations are also shown as on the Topographic Photomap sheets. The map base is a green and black duotone printing. Maps based on Orbiter III photography have a contour interval of 200 meters with 100 meter supplementary contours. Maps based on the higher altitude Orbiter V photography have a contour interval of 400 meters with 200 meter supplements. Contour information is not shown in areas lacking stereoscopic photographic coverage.

Sheets published by ACIC were developed from a 1:250,000 mosaic base which was produced by rectifying and assembling Lunar Orbiter medium resolution photographs to control. Reproduction of the mosaic base with the overprint described above resulted in the photomap sheets. A 1:25,000 mosaic base was also produced by rectifying and assembling Lunar Orbiter high resolution photographs. Difficulty in obtaining an adequate fit of the high resolution photographs to control points, due to the effects of relief displacement and tilt, resulted in the production of many semi-controlled photomaps in the 1:25,000 series.

The base mosaics and individual Orbiter photos were also used to delineate features for the Topographic Map and some later sheets contain additional detail compiled from Apollo Mission photography. In the ACIC compilations, contours for both the Topographic Photomap and Map Series were developed by interpolation between analytically developed control points with adjustment to mosaic imagery in the Topographic Photomap. TOPOCOM employed stereo-plotting equipment to compile feature positions and contour information for lunar map manuscripts. However, the segmented framelet form of Lunar Orbiter photographs prevented continuous compilation within each photo frame and further adjustment of individual framelet model compilations was required.

Area coverage of 1:250,000 and 1:25,000 scale sheets are shown in Map Indices I(6) and I(8) respectively.

Aristarchus 4.3.2.1

Censorinus 4.3.2.2

Copernicus 4.3.2.3

Fra Mauro 4.3.2.4

Gassendi 4.3.2.5

Hipparchus 4.3.2.6

Marius F 4.3.2.7

Mosting C 4.3.2.8

Prinz 4.3.2.9

Rima Hadley 4.3.2.10

Rima Bode II 4.3.2.11

Rima Hyginus 4.3.2.12

Rimae Littrow 4.3.2.13

Tycho 4.3.2.14

4.3.2.1 ARISTARCHUS (ORBITER V SITE 48)
(Published by ACIC)

Lunar Topographic Map
1st Edition January 1972
Scale: 1:250,000
Projection: Transverse Mercator
Sheet Size: 21" x 31.5"

The extent of coverage for the Topographic Map is 20°30'N to 26°18'N and 45°05'W to 49°30'W. The map was compiled from Lunar Orbiter Mission V medium resolution frames 194 to 201. The map is based on the horizontal datum defined by the Aristarchus (1969) Control System described in Section 3.3.1.26 and has a horizontal accuracy of 225 meters expressed at 90% probability and a vertical accuracy range of ± 104 to ± 517 meters (90% probability).

4.3.2.2 CENSORINUS (ORBITER V SITE 12)
(Published by TOPOCOM)

Lunar Photomap
1st Edition May 1969
Scale: 1:250,000
Projection: Transverse Mercator
Sheet Size: 18" x 24"

Lunar Photomaps A and B
1st Edition May 1969
Scale: 1:25,000
Projection: Transverse Mercator
Sheet Size: 28" x 42"

The extent of coverage of the 1:250,000 scale map is 1°13'N to 2°13'S and 31°17'E to 35°20'E. The 1:25,000 scale map's coverage is 0°09'37"S to 9°39'20"S and 32°04'25"E to 33°43'E. These products use Lunar Orbiter Mission V medium and high resolution frames 63 for the 1:250,000 and 1:25,000 respectively. The Photomap products are based on a horizontal and vertical datum defined by the Censorinus (1969) Control System described in Section 3.3.1.27. Photomap margin data reflects a horizontal accuracy of 144 meters, with the 1:250,000 scale product showing a ± 262 meter vertical accuracy, all expressed at 90% probability. However, these accuracy statements apply to control data used rather than actual map accuracy.

4.3.2.3 COPERNICUS (ORBITER V SITE 37)
(Published by TOPOCOM)

Lunar Photomap
1st Edition December 1969
Scale: 1:250,000
Projection: Transverse Mercator
Sheet Size: 21" x 24"

Lunar Topographic Photomap
1st Edition January 1971
Scale: 1:250,000
Projection: Transverse Mercator
Sheet Size: 21" x 24"

Lunar Topographic Map
1st Edition January 1971
Scale: 1:250,000
Projection: Transverse Mercator
Sheet Size: 21" x 24"

The extent of coverage for these 1:250,000 scale sheets is 7°55'N to 12°30'N and 18°40'W to 21°55'W. These products were compiled from Lunar Orbiter Mission V medium resolution frames 150-157. All of the maps are based on the datum defined by the Copernicus (1969) Control System described in Section 3.3.1.28. The Lunar Photomap and Topographic Photomap express a horizontal accuracy of 1184 meters (90% probability). The Topographic Map shows a horizontal accuracy of 88 meters (90% probability). The Topographic Photomap and Topographic Map shows a vertical accuracy range of ± 97 to ± 585 meters (90% probability). However, these accuracy statements apply to control data used rather than actual map accuracy.

4.3.2.4 FRA MAURO (ORBITER III SITE 23)
(Published by ACIC)

Lunar Photomap
1st Edition June 1969
Scale: 1:250,000
Projection: Transverse Mercator
Sheet Size: 19" x 19"

Lunar Topographic Photomap
1st Edition June 1969
2nd Edition December 1969
Projection: Transverse Mercator
Sheet Size: 19" x 19"

Lunar Topographic Map
1st Edition April 1970
Scale: 1:250,000
Projection: Transverse Mercator
Sheet Size: 19" x 20"

Lunar Photomap
1st Edition August 1969
Scale: 1:25,000
Projection: Transverse Mercator
Sheet Size: 24" x 43"

The extent of coverage for the 1:250,000 scale sheets is 2°30'S to 3°30'S and 15°30'W to 19°15'W. The 1:25,000 scale sheet provides coverage from 3°07'S to 3°56'S and 17°08'W to 17°34'W.

These products were compiled from Lunar Orbiter Mission III medium and high resolution frames 132-135. The 1:25,000 Lunar Photomap used high resolution frame 133.

The Lunar Photomaps and the first edition of the Topographic Photomap are based on the Fra Mauro (June 1969) Control System described in Section 3.3.1.29. The 1:25,000 sheet was constructed as a semi-controlled mosaic referenced to this system. The second editions of the Topographic Photomap and the Topographic Map were produced on the corrected datum defined by the Fra Mauro (October 1969) Control System which is also described in referenced Section.

The 1:250,000 Photomap and Topographic Photomap sheets have an evaluated horizontal accuracy of 1600 meters (90% probability) with respect to their identified datum. The 1:25,000 sheet has a relative accuracy of 106 meters. The Topographic Map has a horizontal accuracy of 180 meters and a vertical accuracy of 85 to 100 meters expressed at 90% probability.

4.3.2.5 GASSENDI (ORBITER V SITE 43.2)
(Published by TOPOCOM)

Lunar Photomaps A and B
1st Edition February 1970
Scale: 1:250,000
Projection: Transverse Mercator
Sheet Size: 20" x 26"

Lunar Topographic Photomap A and B
1st Edition October 1971
Scale: 1:250,000
Projection: Transverse Mercator
Sheet Size: 20" x 26"

Lunar Topographic Maps A and B
1st Edition December 1971
Scale: 1:250,000
Projection: Transverse Mercator
Sheet Size: 20" x 26"

The extent of coverage for these 1:250,000 scale sheets is 13°25'S to 20°40'S and 37°55'W to 42°05'W. (Sheets A - 13°25'S to 17°00'S and 37°55'W to 41°45'W; Sheets B - 16°50'S to 20°40'S and 38°07'W to 42°45'W.) These products were compiled from Lunar Orbiter Mission V medium resolution frames 177-180. All of the maps are based on the datum defined by the Gassendi (1969) Control System described in Section 3.3.1.30. The Lunar Photomaps and Topographic Photomaps have a horizontal accuracy of 692 meters expressed at 90% probability. The Topographic Maps show a horizontal accuracy of 78 meters expressed at a 90% probability. The Topographic Photomaps and Topographic Maps have a vertical accuracy range of ± 138 to ± 263 meters expressed at 90% probability. However, these accuracy statements apply to control data used rather than actual map accuracy.

4.3.2.6 HIPPARCHUS (ORBITER V SITE 24)
(Published by TOPOCOM)

Lunar Photomap
1st Edition January 1970
Scale: 1:250,000
Projection: Transverse Mercator
Sheet Size: 18" x 20"

Lunar Topographic Photomap
1st Edition November 1970
Scale: 1:250,000
Projection: Transverse Mercator
Sheet Size: 18" x 20"

Lunar Topographic Map
1st Edition March 1971
Scale: 1:250,000
Projection: Transverse Mercator
Sheet Size: 18" x 20"

The extent of coverage for these 1:250,000 scale sheets is 2°55'S to 6°10'S and 20°05'E to 5°25'E. These products were compiled from Lunar Orbiter Mission V medium resolution frames 98-101. All of the maps are based on the datum defined by the Hipparchus (1969) Control System described in Section 3.3.1. The Lunar Photomap and Topographic Photomap state a horizontal accuracy of 642 meters expressed at 90% probability. The Topographic Map states a horizontal accuracy of 82 meters expressed at 90% probability. The Topographic Photomap and Topographic Map state a vertical accuracy range of ± 164 to ± 441 meters expressed at 90% probability. However, these accuracy statements apply to control data used rather than actual map accuracy.

4.3.2.7 MARIUS F. (ORBITER V SITE 51)
(Published by TOPOCOM)

Lunar Photomap
1st Edition January 1970
Scale: 1:250,000
Projection: Transverse Mercator
Sheet Size: 22" x 23"

Lunar Topographic Photomap
1st Edition August 1970
Scale: 1:250,000
Projection: Transverse Mercator
Sheet Size: 22" x 23"

Lunar Topographic Map
1st Edition April 1971
Scale: 1:250,000
Projection: Transverse Mercator
Sheet Size: 22" x 23"

The extent of coverage for these 1:250,000 scale sheets is 11°25'N to 15°15'N and 54°20'W to 57°55'W. These products were compiled from Lunar Orbiter Mission V medium resolution frames 210-217. All of the maps are based on the datum defined by the Marius F (1969) Control System described in Section 3.3.1.32. The Lunar Photomap and Topographic Photomap state a horizontal accuracy of 697 meters (90% probability). The Topographic Map states a horizontal accuracy of 103 meters expressed at 90% probability. The Topographic Photomap and Topographic Map have a vertical accuracy range of ± 136 to ± 609 meters (90% probability). However, these accuracy statements apply to control data used rather than actual map accuracy.

4.3.2.8 MOSTING C (ORBITER III SITE 18)
(Published by ACIC)

Lunar Photomap
1st Edition August 1969
Scale: 1:250,000
Projection: Transverse Mercator
Sheet Size: 19" x 19"

Lunar Topographic Photomap
1st Edition December 1969
Scale: 1:250,000
Projection: Transverse Mercator
Sheet Size: 19" x 19"

Lunar Photomaps A-B
1st Edition December 1969
Scale: 1:25,000
Projection: Transverse Mercator
Number of Sheets: 2
Sheet Size: 28.5" x 44.5"

The extent of coverage for the 1:250,000 scale sheets is 1°00'S to 3°30'S and 7°00'W to 9°30'W. The 1:25,000 scale sheets provide coverage from 1°30'S to 2°30'S and 7°36'W to 8°28'W. These products were compiled from Lunar Orbiter Mission III medium and high resolution frames 112-115. The Photomaps are based on the horizontal datum defined by the Mosting C (1969) Control System described in Section 3.3.1.33. The 1:250,000 scale products have a horizontal accuracy of 1100 meters expressed at 90% probability. The 1:25,000 scale sheets are constructed of semi-controlled mosaics with a 105 meter relative horizontal accuracy. The Topographic Photomap has a vertical accuracy of 65 to 165 meters expressed at 90% probability.

4.3.2.9 PRINZ (ORBITER V SITE 46)
(Published by TOPOCOM)

Lunar Photomap
1st Edition April 1970
Projection: Transverse Mercator
Scale: 1:250,000
Sheet Size: 28" x 32"

Lunar Topographic Photomap
1st Edition December 1970
Projection: Transverse Mercator
Scale: 1:250,000
Sheet Size: 28" x 32"

Lunar Topographic Map
1st Edition May 1971
Scale: 1:250,000
Projection: Transverse Mercator
Sheet Size: 28" x 32"

The extent of coverage for these 1:250,000 scale sheets is 24°05'N to 30°25'N and 41°00'W to 45°55'W. These products were compiled from Lunar Orbiter Mission V medium resolution frames 186-193. All of the maps are based on the horizontal datum defined by the Prinz (1970) Control System described in Section 3.3.1.34. The Lunar Photomap and Topographic Photomap express a horizontal accuracy of 1188 meters (90% probability). The Topographic Map has 126 meter horizontal accuracy expressed at 90% probability. The Topographic Photomap and Topographic Map express a vertical accuracy range of ± 131 to ± 915 meters (90% probability). However, these accuracy statements apply to control data used rather than actual map accuracy.

4.3.2.10 RIMA HADLEY (ORBITER V SITE 26.1)
(Published by TOPOCOM)

Lunar Photomaps A and B
1st Edition April 1970
Scale: 1:250,000
Number of Sheets: 2
Projection: Transverse Mercator
Sheet Size: 22" x 24"

Lunar Topographic Photomaps A and B
1st Edition November 1970
Scale: 1:250,000
Number of Sheets: 2
Projection: Transverse Mercator
Sheet Size: 22" x 24"

Lunar Topographic Maps A and B
1st Edition January 1971
Scale: 1:250,000
Projection: Transverse Mercator
Number of Sheets: 2
Sheet Size: 22" x 24"

The extent of coverage for these 1:250,000 scale maps is 22°05'N to 29°55'N and 0°45'E to 5°30'E. (Sheets A - 26°05'N to 29°55'N and 0°55'E to 5°30"E; Sheets B - 22°05'N to 26°15'N and 0°45'E to 5°00'E). These products were compiled from Lunar Orbiter Mission V medium resolution frames 104-107. All of the maps are based on the datum defined by the Rima Hadley (1970) Control System described in Section 3.3.1.35. The horizontal accuracies for the maps of this site are stated as follows: Lunar Photomaps - 1167 meters; Topographic Photomaps - 1164 meters; Topographic Maps - 486 meters, all expressed at a 90% probability. The Topographic Photomaps and Topographic Maps have a vertical accuracy statement of ± 250 meters expressed at a 90% probability. However, these accuracy statements apply to control data used rather than actual map accuracy.

4.3.2.11 RIMA BODE II (ORBITER V SITE 29)
(Published by ACIC)

Lunar Photomap
1st Edition November 1969
Scale: 1:250,000
Projection: Transverse Mercator
Sheet Size: 18" x 22"

Lunar Topographic Photomap
1st Edition December 1969
Scale: 1:250,000
Projection: Transverse Mercator
Sheet Size: 18" x 22"

Lunar Topographic Map
1st Edition August 1970
Scale: 1:250,000
Projection: Transverse Mercator
Sheet Size: 18" x 22"

The extent of coverage for these 1:250,000 scale sheets is 11°00'N to 14°40'N and 2°10'W to 5°30'W. These products were compiled from Lunar Orbiter Mission V medium resolution frames 120-123. All of the maps are based on the horizontal datum defined by the Rima Bode II (1969) Control System described in Section 3.3.1.38. The Lunar Photomap and Topographic Photomap have a horizontal accuracy of 950 meters expressed at 90% probability. The Topographic Map has a horizontal accuracy of 180 meters expressed at 90% probability. The vertical accuracy of the Topographic Photomap and Topographic Map, expressed at a 90% probability, ranges from ± 150 to ± 420 meters.

4.3.2.12 RIMA HYGINUS (ORBITER V SITE 23.1)
(Published by TOPOCOM)

Lunar Photomap
1st Edition August 1969
Scale: 1:250,000
Projection: Transverse Mercator
Sheet Size: 18" x 22"

Lunar Topographic Photomap
1st Edition January 1970
2nd Edition October 1970
Scale: 1:250,000
Projection: Transverse Mercator
Sheet Size: 18" x 22"

Lunar Topographic Map
1st Edition November 1970
Scale: 1:250,000
Projection: Transverse Mercator
Sheet Size: 18" x 22"

The extent of coverage for these 1:250,000 scale sheets is 6°10'N to 9°50'N and 4°00'E to 7°20'E. These products were compiled from Lunar Orbiter Mission V medium resolution frames 94-97. All of the maps are based on the datum defined by the Rima Hyginus (1969) Control System described in Section 3.3.1.36. They express a horizontal accuracy of 591 meters (90% probability) and a vertical accuracy range of ± 227 to 503 meters (90% probability) as stated on the Topographic Photomap and Topographic Map. However, these accuracy statements apply to control data used rather than actual map accuracy.

The second edition of the Topographic Photomap reflects an improved compilation of vertical information. The first edition did not provide satisfactory adjustment of effects of individual photo framelet distortions.

4.3.2.13 RIMAE LITTROW (ORBITER V SITE 14)
(Published by TOPOCOM)

Lunar Photomap
1st Edition June 1969
2nd Edition August 1969
Scale: 1:250,000
Projection: Transverse Mercator
Sheet Size: 20" x 24"

Lunar Topographic Photomap
1st Edition October 1969
2nd Edition May 1970
Scale: 1:250,000
Projection: Transverse Mercator
Sheet Size: 20" x 24"

Lunar Topographic Map
1st Edition January 1970
2nd Edition May 1970
Scale: 1:250,000
Projection: Transverse Mercator
Sheet Size: 20" x 24"

The extent of coverage for these 1:250,000 scale sheets is 20°05'N to 24°15'N and 27°25'E to 31°20'E. These products were compiled from Lunar Orbiter Mission V medium resolution frames 66-69. All of the maps are based on the datum defined by the Rima Littrow (1969) Control System described in Section 3.3.1.37. A horizontal accuracy of 678 meters (90% probability) and a vertical accuracy range of ± 392 to ± 676 meters (90% probability) is stated on the Topographic Photomap and Topographic Map. However, these accuracy statements apply to control data used rather than actual map accuracy.

The second edition of these sheets reflects an improved compilation of vertical information. The first edition did not provide satisfactory adjustment of effects of individual photo framelet distortions.

4.3.2.14 TYCHO (ORBITER V SITE 30)
(Published by TOPOCOM)

Lunar Photomaps A and B
1st Edition October 1969
Scale: 1:250,000
Projection: Transverse Mercator
Number of Sheets: 2
Sheet Size: 22" x 34"

Lunar Topographic Photomaps A and B
1st Edition August 1971
Scale: 1:250,000
Projection: Transverse Mercator
Number of Sheets: 2
Sheet Size: 22" x 34"

Lunar Topographic Maps A and B
1st Edition September 1971
Scale: 1:250,000
Projection: Transverse Mercator
Number of Sheets: 2
Sheet Size: 22" x 34"

The extent of coverage for these 1:250,000 scale sheets is 38°25'S to 45°35'S and 7°25'W to 16°15'W. Sheets A - 38°25'S to 41°58'S and 7°25'W to 15°30'W; Sheets B - 41°45'S to 45°35'W to 16°16'W.

These products were compiled from Lunar Orbiter Mission V medium resolution frames 125-128. All of the maps are based on the datum defined by preliminary values from the Tycho (1971) Control System described in Section 3.3.1.39. The Lunar Photomap and Topographic Photomap express a horizontal accuracy of 1883 meters (90% probability). The Topographic Map has a horizontal accuracy of 423 meters expressed at a 90% probability. The vertical accuracy of the Topographic Photomap is ± 423 to ± 1146 meters and the Topographic Map is ± 696 to ± 1885 meters, expressed at a 90% probability. However, these accuracy statements apply to control data used rather than actual map accuracy.

4.3.3 RANGER LUNAR CHARTS

Ranger Lunar Charts were produced by ACIC during 1964-1965 using photography acquired on Ranger Missions VII, VIII, IX. Individual charts were produced at scales ranging from 1:400 - 1:1,000,000 on a Mercator projection with the scale at 11°00'45"S. A sheet size of 22" x 29" was used except for Chart RLC-2 which is 29" x 31". Details of medium scale sheets are provided in Section 4.2.3.

These products were compiled from photographs recorded from the Ranger Television Camera systems (both narrow and wide angle fields) before impacting the lunar surface. The various publication scales were selected to most completely portray imagery contained in the available photography. Extensive photo rectification was required to size the photographs to the selected scales and control. All of the sheets of this series are based on the ACIC Selenodetic System (1965).

Relief is expressed by shadient portrayal, spot elevations and crater depth values. The relief is produced by a duotone printing using black and green inks. Each sheet contains a black overprint of projection, lunar nomenclature, crater depths and spot elevations. A red overprint is used to show the spacecrafts trajectory trace, each camera track, photo coverage and the outline of the succeeding chart plus the impact point. A black printing, void of overprint information, is also available to give the user an unobstructed view of the lunar surface detail depicted by the shaded relief drawing.

Feature names are taken from the IAU's accepted list. Supplementar features are associated with the named features through the addition of identifying letters.

Chart margin information includes chart location, diagram, and general notes and statements on the control system used, lunar nomenclature, elevation data, and relief portrayal.

RANGER VII LUNAR CHARTS
1st Edition October 1964

CHART	EXTENT OF COVERAGE PER SHEET
RLC-3 Bonpland H Scale 1:100,000	19°45'W to 21°45'W 10°10'S to 11°45'S
RLC-4 Bonpland PQC Scale 1:10,000	20°30'W to 20°39'W 10°37'S to 10°42'S
RLC-5 Unnamed Scale 1:1,000	20°34'20"W to 20°35'10"W 10°37'50"S to 10°38'30"S

RANGER VIII LUNAR CHARTS
1st Edition March 1966

CHART	EXTENT OF COVERAGE PER SHEET
RLC-7 Sabine Scale 1:250,000	19°E to 24°E 3°N to 1°N
RLC-8 Sabine D Scale 1:100,000	22°30'E to 24°30'E 2°45'N to 1°09'N
RLC-9 Sabine DM Scale 1:50,000	23°30'E to 24°30'E 2°45'N to 1°57'N
RLC-10 Sabine EF Scale 1:15,000	24°16'E to 24°34'E 2°44'N to 2°29'36"N
RLC-11 Sabine EB Scale 1:5,000	24°30'07"E to 24°36'07"E 2°42'48"N to 2°38'N
RLC-12 Sabine EBF Scale 1:2,000	24°34'15"E to 24°36'25"E 2°42'36"N to 2°41'15"N

RANGER IX LUNAR CHARTS
1st Edition May 1966

CHART	EXTENT OF COVERAGE PER SHEET
RLC-14 Alphonsus Scale 1:250,000	5°W to 0° 11°30'S to 15°30'S
RLC-15 Alphonsus GA Scale 1:50,000	2°50'W to 1°50'W 12°25'S to 13°13'S
RLC-16 Alphonsus GP Scale 1:10,000	2°28'30"W to 2°16'30"W 12°45'24"S to 12°55'S
RLC-17 Alphonsus GLH Scales 1:2,000 & 1:400	2°22'30"W to 2°21'15"W 12°49'07"S to 12°50'45"S

4.3.4 SURVEYOR LUNAR PHOTOMAP AND MAP SERIES

The Surveyor lunar landing site maps were produced in 1967-1968 in photomap and lunar map form by ACIC and TOPOCOM in support of study of Surveyor Missions I, III, and VI results. The maps are identified by the number of the Surveyor landing vehicle whose location is shown c each sheet. The 1:2,000 and 1:1,000 scale maps were produced both in photomap and lunar map form, while the 1:500 and 1:100 scale maps were produced only as lunar maps. Enlarged high resolution photographic framelets from Lunar Orbiter Missions I, II and III were used to produce the image bases for these various sites in an effort to provide maximum definition of site features and topography.

Vertical and horizontal positions are generally based on local analytical photogrammetric triangulation, using Lunar Orbiter mission site photographs and preliminary Photo Support Data. These control solutions only provided an array of control points supporting the relative positioning of features on the map sheets. The absolute selenographic values shown are not considered to be reliable.

Contour information on the 1:2,000 scale maps is shown at a 10 meter interval with five meter supplementary contours. A two meter interval and a one meter supplementary contour are depicted on the 1:500 scale maps. All contours are expressed as radius vectors but should only be used for the relative elevation information shown.

The Surveyor Photomap series reflects photomosaic detail, lithographed in black and overprinted in red with contours, crater depths and rim elevation values. The map margin information contains vertical and horizontal reliability statements, relative error information, and a map legend describing the overprinted information.

The Surveyor Lunar Map Series depicts hypsography by shadient relief, contours, rim elevations above surrounding terrain, and crater depths. The base map is a green-black duotone printing. Relief values are overprinted in black; contours in red.

In constructing the Surveyor maps, portions of individual high resolution Lunar Orbiter photo framelets were enlarged to a scale of 1:2,000 and were mosaiced together with adjustment to the contained film reseau. The photomosaic base was reproduced with described overprints resulting in the photomap sheets. The Lunar Map series at 1:2,000 was produced by using the base mosaic which provided control for delineation of features on the shadient relief drawings. An enlargement of the mosaic similarly served in compilation of the 1:500 scale maps. Contours and spot elevations were interpolated from the analytical photogrammetric control solutions assisted by photometric tracings and measurements.

Surveyor Site I Mapping 4.3.4.1

Surveyor Site III Mapping 4.3.4.2

Surveyor Site VI Mapping 4.3.4.3

4.3.4.1 SURVEYOR SITE I MAPPING

Lunar Photomap
1st Edition, January 1968
Scale: 1:2,000
Projection: Mercator
Sheet Size: 24" x 30"
Published by: ACIC

Lunar Map
1st Edition, January 1968
Scale: 1:2,000
Projection: Mercator
Sheet Size: 24" x 30"
Published by: ACIC

Lunar Map
1st Edition, January 1968
Scale: 1:500
Projection: Mercator
Sheet Size: 24" x 30"
Published by: ACIC

Pictorial Lunar Map
1st Edition, October 1967
Scale: 1:100
Projection: True Orthographic
Sheet Size: 39" x 43"
Published by: TOPOCOM

1. 1:500-1:2,000 Surveyor I Site mapping was produced on a Mercator projection (standard parallels at 2°30"N-S) with coverage from 2°31'S to 2°33'S and 43°21'12"W to 43°24'W for the 1:2,000 scale maps. The 1:500 scale map provides coverage from 2°31'45"S to 2°32'15"S and 43°22'15"W to 43°22'57"W. The maps were compiled from Lunar Orbiter III high resolution frome 183, framelet numbers 872 through 878. Framelets 875 and 876 were used to provide the base imagery for the 1:500 scale map. The map margin contains a site location diagram keyed to a LAC index and another keyed to ORB I-9.2 (100) and ORB III-12 (100) map outlines, both of which overlap the site. These Surveyor I Site maps have an evaluated horizontal accuracy of three meters and a vertical accuracy of ten meters, both expressed at 90% probability.

2. The 1:100 scale Pictorial Map was produced on a true Orthographic Projection based on the local lunar surface with the Surveyor I Site as its center. The extent of coverage is 46 meters in any direction from portions of the Surveyor I camera station. The base imagery was compiled from Lunar Orbiter III high resolution frame 183. The map margin contains a site location diagram keyed to ORB III-12 (100) map outline. This sheet contains no overprinted contour or relative height information and its accuracy is unevaluated.

4.3.4.2 SURVEYOR SITE III MAPPING
(Published by TOPOCOM)

Lunar Photomap
1st Edition, January 1968
Scale: 1:2,000
Projection: Mercator
Sheet Size: 24" x 30"

Lunar Map
1st Edition, February 1968
Scale: 1:500
Projection: Mercator
Sheet Size: 24" x 28"

Surveyor III Site mapping was produced on a Mercator projection (standard parallels at 2°30'N-S) with coverage from 3°11'12"S to 3°13'12"S and 23°21'36"W to 23°24'24"W for the 1:2,000 scale map. The 1:500 scale map provides coverage from 3°11'48"S to 3°12'18"S and 23°22'42"W to 23°23'18"W. The maps were compiled from portions of Lunar Orbiter III high resolution frame 154. Map margin information includes a site location diagram keyed to a LAC index and another keyed to ORB I-7 (100) and ORB III-9 (100) map outlines, both of which overlap the site. The maps compiled for Surveyor III Site have an evaluated horizontal accuracy of three meters and a vertical accuracy of ten meters, both expressed at a 90% probability.

4.3.4.3 SURVEYOR SITE VI MAPPING
(Published by TOPOCOM)

Lunar Photomap (Experimental)
1st Edition March 1969
Scale: 1:1,000 (approximate)
Projection: Mercator
Sheet Size: 26" x 30"

The Surveyor VI Site map was produced on a Mercator projection (standard parallels at 2°30'N-S) with coverage from 0°28'45"N to 0°30'13"N and 1°23'17"W to 1°24'40"W. The base imagery was compiled from Lunar Orbiter II high resolution frame 121 using portions of framelets 265 through 267. The map margin contains a site location diagram keyed to LAC 59 with reference to ORB II-8 (100) map outline in which the Surveyor Site is located. The contour interval is one meter with 50-centimeter supplementary contours.

The map datum is an arbitary one based on the lunar surface surrounding the Surveyor VI landing site. Contour values, as stated on the map, are relative to measurements made from the assumed landing site datum. The accuracy of the sheet is unevaluated.

4.3.5 LUNAR TOPOGRAPHIC ORTHOPHOTOMAP (LTO) AND LUNAR ORTHOPHOTOMAP (LO) SERIES (Published by DMATC)

Lunar Topographic Orthophotomaps and Lunar Orthophotomaps
Scale: 1:250,000
Projection: Transverse Mercator
Sheet Size: 25.5"x26.5"

The Lunar Topographic Orthophotomap and Lunar Orthophotomap Series are the first comprehensive and continuous mapping to be accomplished from Apollo Mission 15-17 mapping photographs. This series is also the first major effort to apply recent advances in orthophotography to lunar mapping. Presently developed maps of this series were designed to support initial lunar scientific investigations primarily employing results of Apollo Mission 15-17 data.

Individual maps of this series cover 4 degrees of lunar latitude and 5 degrees of lunar longitude constituting 1/16 of the area of a 1:1,000,000 scale Lunar Astronautical Chart (LAC) (Section 4.2.1). Their alphanumeric identification (example -- LTO38B1) consists of the designator LTO for topographic orthophoto editions or LO for orthophoto editions followed by the LAC number in which they fall, followed by an A, B, C or D designator defining the pertinent LAC quadrant and a 1, 2, 3 or 4 designator defining the specific sub-quadrant actually covered. The following designation (250) identifies the sheets as being at 1:250,000 scale. Map indexes I(6a) and II(4), which show the location of available maps, also serve to provide a graphic explanation of sheet identification numbers.

The LTO editions display 100 meter contours, 50 meter supplemental contours and spot elevations in a red overprint to the orthophoto base which is lithographed in black and white. LO editions are identical except that all relief information is omitted and selenographic graticule is restricted to border ticks, presenting an unencumbered view of lunar features imaged by the photographic base. Both editions carry a Lunar Transverse Mercator (LTM) Grid to facilitate reference and relation of features by rectangular coordinates. The LTM Grid is shown by border ticks in red.

Map margin information includes a location diagram keyed to the LAC System and qualifying and explanatory statements on the photography, control, datum, nomenclature, grid system, relief information and accuracy of data contained. More recently published sheets portray lunar longitude in a 360 degree system rather than 0-180 degrees east or west.

The control basis for this map series is the Apollo 15 (April 1973) Control System described in Section 3.2.3.5. The orthophotography and relief information have been developed through analytical stereoplotter compilation with Apollo 15-17 mapping photography. In isolated cases, Apollo panoramic and Lunar Orbiter Mission photography have been used to fill coverage gaps. In other instances, there are areas where relief information is limited or complete voids exist. More specific commentary is included with the listing of available map sheets.

The evaluated horizontal and vertical accuracy of subject series at 90% probability generally ranges from 160 to 500 meters and 30 to 115 meters respectively relative to the Apollo 15 (April 1973) Datum. In instances where significant inaccuracy exists in relating map sheets to this Datum, a statement of accuracy with respect to local datum is also provided.

Map No.	Map Name	Edition & Date	Remarks
LO & LTO 38B1	HUMASON	1st Edition, Jul 73	Void North of
LTO 38B1	HUMASON	2nd Edition, Mar 74	31°00'N.
LO & LTO 38B2	NIELSEN	1st Edition, Aug 73	Void North of 31°00'N.
LTO 38B2	NIELSEN	2nd Edition, Apr 74	Rectified imagery extended to cover Crater Nielsen.
LO & LTO 38B3	FREUD	1st Edition, Jul 73	Void South of 26°N.
LTO 38B3	FREUD	2nd Edition, Feb 74	Rectified imagery extended to cover Crater Freud.
LO & LTO 38B4	ZINNER	1st Edition, Jul 73	Void South of
LTO 38B4	ZINNER	2nd Edition, Feb 74	26°N.
LO & LTO 39A1	KRIEGER	1st Edition, Jul 73	Void North of 31°25'N.
LO & LTO 39A2	ANGSTOM	1st Edition, Jul 73	Void North of 13°20'N.
LO & LTO 39A3	PRINZ	1st Edition, Aug 73	Void South of
LTO 39A3	PRINZ	2nd Edition, Apr 74	26°10'S.
LO & LTO 39A4	VAISALA	1st Edition, Aug 73	Void South of 26°20'N.
LTO 39A4	VAISALA	2nd Edition, Mar 74	Rectified imagery extended to cover Crater Vaisala.
LO & LTO 39B1	FEDEROV	1st Edition, Mar 74	Void North of 31°15'N.
LO & LTO 39B2	DELISLE	1st Edition, Mar 74	Void North of 31°15'N.

Map No.	Map Name	Edition & Date	Remarks
LO & LTO 39B3	DIOPHANTUS	1st Edition, Mar 74	
LO & LTO 39B4	ARTSIMOVICH	1st Edition, Mar 74	
LO & LTO 40A1	CAVENTOU	1st Edition, Apr 74	Void North of 31°15'N.
LO & LTO 40A2	MCDONALD	1st Edition, Apr 74	Void North of 31°00'N.
LO & LTO 40A3	LAMBERT	1st Edition, Apr 74	
LO & LTO 40A4	LA HIRE	1st Edition, Apr 74	
LO & LTO 40B1	SAMPSON	1st Edition, Mar 74	Void North of 30°30'N.
LO & LTO 40B2	LANDSTEINER	1st Edition, May 74	Orthophotography and contours restricted to South of 29°50'N.
LO & LTO 40B3	KOVALEVSKIJ	1st Edition, Apr 74	
LO & LTO 40B4	HEINRICH	1st Edition, Apr 74	
LO & LTO 40C2	PUPIN	1st Edition, Apr 74	Void South of 20°45'N.
LO & LTO 41A3 LTO 41A3	SPURR SPURR	1st Edition, Sep 73 2nd Edition, Sep 74	
LO & LTO 41A4	BEER	1st Edition, May 74	
LO & LTO 41B3	JOY	1st Edition, Jan 74	
LO & LTO 41B4	HADLEY	1st Edition, Jan 74	
LO & LTO 41C1	CONON	1st Edition, Aug 74	
LO & LTO 41C2	GALEN	1st Edition, Apr 74	
LO & LTO 41C3	BOWEN	1st Edition, Apr 74	
LO & LTO 41C4 LTO 41C4	YANGEL YANGEL	1st Edition, Jun 74 2nd Edition, Oct 74	Southwest corner is void.
LO & LTO 41D1	WALLACE	1st Edition, May 74	Southwest corner is void.
LO & LTO 41D2	HUXLEY	1st Edition, May 74	

Map No.	Map Name	Edition & Date	Remarks
LO & LTO 42A3	BANTING	1st Edition, Feb 74	Void North of 27°50'N.
LO & LTO 42A4	LINNE	1st Edition, Apr 74 2nd Edition, Nov 74	Northeast corner is void.
LO & LTO 42B3	VERY	1st Edition, Mar 74	Void North of 26°45'N.
LO & LTO 42B4	SARABHAI	1st Edition, Mar 74	Void North of 26°25'N.
LO & LTO 42C1	DESEILLIGNY	1st Edition, May 74	
LO & LTO 42C2	CLERKE	1st Edition, May 74	
LO & LTO 42C3	DAWES	1st Edition, May 74	
LTO 42C3	DAWES	2nd Edition, Feb 75	
LO & LTO 42C4	BRACKETT	1st Edition, Aug 74	
LO & LTO 42D1	HORNSBY	1st Edition, Aug 73	
LTO 42D1	HORNSBY	2nd Edition, May 74	
LO & LTO 42D2	BESSEL	1st Edition, May 74	
LO & LTO 42D3	MENELAUS	1st Edition, May 74	
LO & LTO 42D4	SULPICIUS GALLUS	1st Edition, May 74	
LO & LTO 43A4	le MONNIER	1st Edition, Nov 74	
LO & LTO 43C1	HILL	1st Edition May 74	Void North of 23°15'N.
LO & LTO 43C3	PROCLUS	1st Edition, May 74	
LO & LTO 43C4	CARMICHAEL	1st Edition, May 74	
LO & LTO 43D1	LITTROW	1st Edition, Oct 74	
LO & LTO 43D1	LITTROW	2nd Edition, Oct 74	
LO & LTO 43D2	FRANCK	1st Edition, May 74	
LO & LTO 43D3	THEOPHRASTUS	1st Edition, Aug 74	
LO & LTO 43D4	VITRUVIUS	1st Edition, May 74	
LO & LTO 44D3	ECKERT	1st Edition, Apr 74	

Map No.	Map Name	Edition & Date	Remarks
LO & LTO 44D4	PEIRCE	1st Edition, Jun 74	
LTO 44D4	PEIRCE	2nd Edition, Oct 74	
LO & LTO 60A1	DAUBREE	1st Edition, Dec 73	Void in southwest corner.
LO & LTO 60A2	AUWERS	1st Edition, Mar 74	
LO & LTO 60B1	PLINIUS	1st Edition, Jul 74	
LO & LTO 60B2	JANSEN	1st Edition, Mar 74	
LO & LTO 61A1	CAJAL	1st Edition, Apr 74	
LO & LTO 61A2	LUCIAN	1st Edition, Apr 74	
LTO 61A2	LUCIAN	2nd Edition, Oct 74	
LO & LTO 61A3	CAUCHY	1st Edition, Oct 74	
LO & LTO 61B1	LYELL	1st Edition, Aug 74	
LO & LTO 61B2	GLAISHER	1st Edition, Mar 74	
LO & LTO 61B3	WATTS	1st Edition, Mar 74	
LO & LTO 61B4	DA VINCI	1st Edition, Nov 73	
LO & LTO 61C1	LAWRENCE	1st Edition, Mar 74	
LO & LTO 61C2	CAMERON	1st Edition, Mar 74	
LO & LTO 61C3	AMVILLE	1st Edition, Mar 74	
LO & LTO 61C4	SECCHI	1st Edition, Mar 74	
LO & LTO 62A1	YERKES	1st Edition, May 74	
LO & LTO 62A2	CURTIS	1st Edition, May 74	
LO & LTO 62A3	SHAPLEY	1st Edition, Mar 74	
LO & LTO 62A4	TEBBUTT	1st Edition, Mar 74	
LO & LTO 62B1	FAHRENHEIT	1st Edition, Aug 74	
LO & LTO 62B2	CONDORCET	1st Edition, Nov 74	Cartographic information lacking in northeast quadrant and North of 15°30'N.

Map No.	Map Name	Edition & Date	Remarks
LO & LTO 62B3	KROGH	1st Edition, Aug 74	
LO & LTO 62B4	AUZOUT	1st Edition, Aug 74	
LO & LTO 62C1	FIRMICUS	1st Edition, Jul 74	
LO & LTO 62C2	DUBYAGO	1st Edition, Jun 74	
LO & LTO 62C3	POMORTSEV	1st Edition, Jun 74	
LO & LTO 62C4	CONDON	1st Edition, Aug 74	
LO & LTO 62D1	ABBOT	1st Edition, Mar 74	
LO & LTO 62D2	DALY	1st Edition, May 74	
LO & LTO 62D3	AMEGHINO	1st Edition, May 74	
LO & LTO 62D4	SMITHSON	1st Edition, Mar 74	
LO & LTO 63C1	KNOX-SHAW	1st Edition, Apr 74	
LO & LTO 63C2	TACHINNI	1st Edition, Sep 74	
LO & LTO 63C3	PEEK	1st Edition, Dec 73	
LO & LTO 63C4	SCHUBERT	1st Edition, Dec 73	
LO & LTO 63D1	BOETHIUS	1st Edition, Aug 74	
LO & LTO 63D3	NOBILI	1st Edition, Aug 74	
LO & LTO 63D4	RESPIGHI	1st Edition, Jun 74	
LO & LTO 64D1	NUNN	1st Edition, Oct 74	
LO & LTO 64D2	ERRO	1st Edition, Sep 74	
LO & LTO 64D3	FOX	1st Edition, Sep 74	
LO & LTO 64D4	MCADIE	1st Edition, Sep 74	
LO & LTO 65A3	GUYOT	1st Edition, Sep 74	Lacking cartographic information North of 11°N.
LO & LTO 65B4	RECHT	1st Edition, Sep 74	Void North of 11°30'N.

Section 4.3.5

Map No.	Map Name	Edition & Date	Remarks
LO & LTO 65C1	KING	1st Edition, Sep 74	
LO & LTO 65C4	ZANSTRA	1st Edition, Sep 74	Southeast corner is void.
LO & LTO 65D2	KATCHALSKY	1st Edition, Sep 74	
LTO 65D2	KATCHALSKY	2nd Edition, Feb 75	
LO & LTO 65D3	ABULWAFA	1st Edition, Feb 75	
LO & LTO 66A3	RUTHERFORD	1st Edition, Nov 74	Lacking cartographic information North of 10°N.
LO & LTO 66B4	GLAUBER	1st Edition, Nov 74	Lacking cartographic information North of 10°50'N.
LO & LTO 66C1	FISCHER	1st Edition, Nov 74	
LO & LTO 66D2	BERGMAN	1st Edition, Nov 74	
LO & LTO 75C1	SCHEELE	1st Edition, Aug 74	
LO & LTO 75C2	NORMAN	1st Edition, Sep 74	
LO & LTO 75D2	WINTHROP	1st Edition, Aug 74	
LO & LTO 76C1	BONPLAND	1st Edition, Sep 74	
LO & LTO 76C2	GUERICKE	1st Edition, Sep 74	
LO & LTO 76D1	EPPINGER	1st Edition, Sep 74	
LO & LTO 76D2	KUIPER	1st Edition, Sep 74	
LO & LTO 77C1	ALBATEGNIUS	1st Edition, Nov 74	Cartographic information lacking in southeast corner.
LO & LTO 77C2	HALLEY	1st Edition, Nov 74	Cartographic information lacking South of 11°30'S.
LO & LTO 77D1	DAVY	1st Edition, Nov 74	
LO & LTO 77D2	AMMONIUS	1st Edition, Oct 74	Lacking cartographic information South of 10°S.
LO & LTO 78A3	ALFRAGANUS	1st Edition, Nov 74	Lacking cartographic information North of 5°30'S.

Map No.	Map Name	Edition & Date	Remarks
LO & LTO 78B3	TORRICELLI	1st Edition, Nov 74	
LO & LTO 78B4	HYPATIA	1st Edition, Nov 74	Lacking cartographic information in northwest corner.
LO & LTO 78C1	KANT	1st Edition, Oct 74	Void South of 11°30'S.
LO & LTO 78C2	MADLER	1st Edition, Sep 74	Void South of 11°30'S.
LO & LTO 78D1	ANDEL	1st Edition, Oct 74	
LO & LTO 78D2	DESCARTES	1st Edition, Nov 74	Lacking cartographic information South of 11°15'S.
LO & LTO 79A2	LEAKEY	1st Edition, Nov 74	Lacking cartographic information North of 2°S.
LO & LTO 79A3	CAPELLA	1st Edition, Nov 74	
LO & LTO 79A4	ISIDORUS	1st Edition, Oct 74	
LO & LTO 79B1	LUBBOCK	1st Edition, Aug 74	Void at 1°S 40°30'E.
LO & LTO 79B2	MESSIER	1st Edition, Apr 74	
LO & LTO 79B3	AMONTONS	1st Edition, Nov 74	
LO & LTO 79B4	GUTENBERG	1st Edition, Aug 74	
LO & LTO 79D1	DAGUERRE	1st Edition, Nov 74	Void South of 11°25'S.
LO & LTO 79D2	GAUDIBERT	1st Edition, Dec 74	Void South of 11°S.
LO & LTO 80A1	GEIKIE	1st Edition, Apr 74	
LO & LTO 80A2	WEBB	1st Edition, Apr 74	
LO & LTO 80A3	BILHARZ	1st Edition, Apr 74	
LO & LTO 80A4	LINDBERGH	1st Edition, Nov 74	
LO & LTO 80B1	MORLEY	1st Edition, Jun 74	
LO & LTO 80B2	MACLAURIN	1st Edition, Aug 74	

Map No.	Map Name	Edition & Date	Remarks
LO & LTO 80B4	ACOSTA	1st Edition, Nov 74	
LO & LTO 80C1	SOMERVILLE	1st Edition, Aug 74	
LO & LTO 80D2	AL-MARRAKUSHI	1st Edition, Nov 74	Cartographic information lacking in southwest corner.
LO & LTO 81A1	RANKINE	1st Edition, Aug 74	
LO & LTO 81A2	GILBERT	1st Edition, Aug 74	
LO & LTO 81B1	HALDANE	1st Edition, Dec 73	
LO & LTO 81B2	RUNGE	1st Edition, Nov 73	
LO & LTO 81B3	WIDMANNSTATTEN	1st Edition, Nov 73	
LO & LTO 81B4	KIESS	1st Edition, Dec 73	
LO & LTO 81C1	KREIKEN	1st Edition, Dec 73	
LO & LTO 81C2	HOUTERMANS	1st Edition, Dec 73	
LO & LTO 82A1	PURKYNE	1st Edition, Dec 73	
LO & LTO 82A2	WYLD	1st Edition, Dec 73	
LO & LTO 82A3	LUDWIG	1st Edition, Dec 73	
LO & LTO 82A4	HIRAYAMA	1st Edition, Dec 73	
LO & LTO 82D1	BRUNNER	1st Edition, Dec 73	
LO & LTO 82D2	GANSKIJ	1st Edition, Dec 73	
LO & LTO 83C1	DANJON	1st Edition, Sep 74	
LO & LTO 83C3	DOBROVOLSKIJ	1st Edition, Jul 73	
LO & LTO 83C4	DELPORTE	1st Edition, Jul 73	
LO & LTO 83D2	SHERRINGTON	1st Edition, Oct 74	
LO & LTO 84D4	VOLKOV	1st Edition, Jul 73	

Map No.	Map Name	Edition & Date	Remarks
LO & LTO 100C1	TITIUS	1st Edition, Dec 74	
LO & LTO 101B1	LITKE	1st Edition, Jul 73	
LO & LTO 101B2	TSIOLKOVSKIJ	1st Edition, Jul 73	
LTO 101B2	BOREALIS	2nd Edition, Jul 73	
LO & LTO 101B3	TSIOLKOVSKIJ AUSTRALIS	1st Edition, Jul 73	
LO & LTO 101B4	BABAKIN	1st Edition, Jul 73	
LTO 101B4	BABAKIN	2nd Edition, Apr 74	
LO & LTO 101C1	NEUJMIN	1st Edition, Jul 73	
LO & LTO 101C2	WATERMAN	1st Edition, Jul 73	Void South of 26°S and East of 126°E.
LO & LTO 102A1	PATSAEV	1st Edition, Jul 73	
LTO 102A1	PATSAEV	2nd Edition, Sep 73	
LTO 102A1	PATSAEV	3rd Edition, Feb 74	
LO & LTO 102A4	FESENKOV	1st Edition, Jul 73	
LO & LTO 102B2	ISAEV	1st Edition, Sep 74	
LO & LTO 102B3	ANDRONOV	1st Edition, Oct 74	Void in southwest corner.
LO & LTO 102D1	STARK	1st Edition, Jul 73	Void South of 27°S.
LTO 102D1	STARK	2nd Edition, Mar 74	
LO & LTO 103A1	GRAVE	1st Edition, Oct 74	
LO & LTO 103A4	RASPLETIN	1st Edition, Oct 74	

4.3.6 OTHER MAPS AND PHOTOMAPS

Included are large scale maps which have not been published as part of a map series. These sheets have been produced to support exploration and/or scientific study of individual lunar sites.

Rima Hadley Photomaps 4.3.6.1

Descarte Topographic Maps and Photomaps . . . 4.3.6.2

Taurus Littrow Topographic Photomaps 4.3.6.3

4.3.6.1 RIMA HADLEY PHOTOMAPS
(Published by ACIC)

Lunar Uncontrolled Photomap
1st Edition, November 1971
Scale: 1:25,000
Projection: Transverse Mercator
Sheet Size: 41"x58"

Lunar Topographic Photomap
1st Edition, February 1972
Scale: 1:25,000
Projection: Transverse Mercator
Sheet Size: 41"x58"

The extent of coverage of these sheets is from 25°35'N to 26°47'N and 3°19'E to 4°15'E. Area coverage is reflected in Map Index I(8a).

The Uncontrolled Photomap was produced to provide a photographic base for timely use by scientific investigators conducting studies of the Apollo 15 landing site area. Extra vehicular activity traverse routes and site locations from which panorama photographs were taken, are shown. Additionally, the Lunar Topographic Photomap portrays relief with 20 meter contours and 10 meter supplementary contours in areas of low relief.

Apollo 15 panoramic photographs 9791-9800 were used in the analytical stereoplotter compilation of relief information for the Topographic photomap. Topographic maps Rima Hadley A & B (Section 4.3.2.10) were used as a control source and the 1:25,000 sheets are therefore related to the Rima Hadley (1970) Control System (Section 3.3.1.35). The Uncontrolled Photomap was constructed through mosaicing of rectified segments of the panoramic photographs with a best overall fit of the assembled mosaic to control data. The photographic base for the Topographic Photomap was compiled by fitting of individual rectified panoramic photo segments to horizontal control data.

The Uncontrolled Photomap is of present value only for the unencumbered picture of the Hadley Rille region it presents. There are large horizontal positional errors in both photographic bases in areas of significant relief. In the case of the Topographic Photomap, contour information has been adjusted to match photographic detail and its continued use is recommended for relative heighting differences portrayed. Its evaluated vertical accuracy for this purpose is ±15 meters at 90% probability.

4.3.6.2 DESCARTE TOPOGRAPHIC MAPS & PHOTOMAPS
(Published by TOPOCOM)

Lunar Photomap
1st Edition, September 1971
Scale: 1:100,000
Projection: Transverse Mercator
Sheet Size: 25"x25"

Lunar Topographic Map
1st Edition, March 1972
Scale: 1:100,000
Projection: Transverse Mercator
Sheet Size: 25"x25"

Lunar Photomap
1st Edition, October 1971
Scale: 1:25,000
Projection: Transverse Mercator
Sheet Size: 28"x31"

Lunar Topographic Photomap
1st Edition, January 1972
Scale: 1:25,000
Projection: Transverse Mercator
Sheet Size: 28"x31"

Lunar Topographic Map
1st Edition, March 1972
Scale: 1:25,000
Projection: Transverse Mercator
Sheet Size: 28"x31"

The Descarte Maps and Photomaps were produced with 1:100,000 scale coverage extending from 8°10'S to 9°50'S and 15°00'E to 17°03'E. 1:25,000 scale coverage extends from 8°44'S to 9°12'S and 15°12'E to 15°50'E. Coverage is portrayed graphically on Index I(8a).

The Photomap products show photomosaic detail assembled from Apollo 14 Hassleblad photographs with the photobase being lithographed in black. Map products are also based on this photography using a green and black duotone printing which carries shadient relief portrayal. Relief is expressed by contours and spot elevations on the Topographic Map and Photomap editions. A 100 meter contour interval with 50 meter supplementary contours is used on 1:100,000 scale products and a 10 meter contour interval with 5 meter supplementary contours appears on the 1:25,000 scale topographic sheets. Map margin information includes a sheet index referenced to a Lunar Astronautical Chart (LAC), vertical and horizontal reliability information and a diagram depicting the sun angle of photographs used.

Map feature locations and relief information are based on analytical stereoplotter compilation of Apollo 14 80mm and 500mm focal length Hassleblad photographs based on Descarte (1971) System (Section 3.3.2.2) control points.

Following are evaluated accuracies of subject sheets with respect to the datum of the Descarte (1971) System.

	Horizontal	Vertical
Photomap, 1:25,000	142 meters	---
Topographic Photomap, 1:25,000	142 meters	181 meters
Topographic Map, 1:25,000	47 meters	181 meters
Photomap, 1:100,000	230 meters	---
Topographic Map, 1:100,000	72 meters	105-181 meters

4.3.6.3 TAURUS LITTROW TOPOGRAPHIC PHOTOMAPS (Published by DMATC)

Lunar Topographic Photomap
1st Edition, September 1972
Scale: 1:25,000
Projection: Transverse Mercator
Sheet Size: 29"x43"

Lunar Topographic Photomap
1st Edition, September 1972
Scale: 1:50,000
Projection: Transverse Mercator
Sheet Size: 33"x30"

Lunar Topographic Photomap
1st Edition, September 1972
Scale: 1:250,000
Projection: Transverse Mercator
Sheet Size: 26"x30"

The Taurus Littrow Photomaps were produced with 1:25,000 scale coverage extending from 19°55'N to 20°25'N and 30°15'E to 31°10'E. The 1:50,000 sheet is canted to obtain coverage of the prime area of interest and has approximate sheet corner values of N19°45'E29°55', N20°50'E30°00', N20°30'E31°30', N19°25'E31°05'. 1:250,000 scale coverage extends from 20°25'18°00'N to 22°00'N and 28°00'E to 34°00'E with a small area of omitted detail at N18°15'E30°45'. Location is graphically shown by Map Index I(8a).

All of these products show photographic detail compiled from Apollo 15 photographs and are lithographed in black. Relief information is printed in red with 10 meter contours portrayed on the 1:25,000 scale sheet, 50 meter contours and 10 meter supplementary contours on the 1:50,000 scale sheet and 100 meter contours and 50 meter supplementary contours appearing on the 1:250,000 scale map. Map margin information includes a sheet index referenced to a Lunar Astronautical Chart (LAC), vertical and horizontal reliability information and a diagram depicting the sun angle of photographs used.

The photo mosaic base for the 1:25,000 and 1:50,000 scale photomaps was compiled from rectified panoramic photographs. The 1:250,000 orthophotomap is based on orthophotography generated from mapping camera photographs. Relief information was developed by analytical stereoplotter compilation and all sheets are based on the Taurus Littrow (1972) Control System (Section 3.3.2.1).

The 1:25,000 and 1:50,000 scale photomaps have evaluated horizontal accuracies of 36-298 meters at 90% probability. The upper limit of this range reflects displacement of photo imagery in upland areas. All three sheets have an evaluated vertical accuracy of 37-64 meters at 90% probability. The 36 meter horizontal accuracy stated in the orthophotomap margin is applicable to the control rather than the photomap. Given accuracy information is with respect to the Taurus Littrow (1972) Control System.

4.4 REFERENCES - LUNAR MAPS

4.4.1 Orthographic Atlas of the Moon, Supplement No. 1 to the Photographic Lunar Atlas, compiled by D. W. G. Arthur and E. A. Whitaker, edited by Gerard P. Kuiper, 1961

4.4.2 Lunar Exploration Site V-12, Censorinus, Project History, NASA Contract No. W-12, 375, TOPOCOM, August 1969

4.4.3 Mapping of Scientific Site V-14 Rimae Littrow, Project History, NASA Contract No. W-12, 375, TOPOCOM, August 1970

4.4.4 Lunar Exploration Site V-23.1 Rima Hyginus, Project History, NASA Contract No. W-12, 375, TOPOCOM, August 1970

4.4.5 Mapping of Scientific Site V-24 Hipparchus, Project History, NASA Contract No. W-12, 375, TOPOCOM, December 1970

4.4.6 Mapping of Scientific Site V-26.1 Rima Hadley, Project History, NASA Contract W-12, 375, TOPOCOM, November 1970

4.4.7 Lunar Exploration Site V-30 Tycho, Project History, NASA Contract W-12, 375, TOPOCOM, July 1970

4.4.8 Mapping of Scientific Site V-37 Copernicus, Project History, NASA Contract W-12, 375, TOPOCOM, December 1970

4.4.9 Mapping of Scientific Site V-46 Prinz, Project History, NASA Contract W-12, 375, TOPOCOM, December 1970

4.4.10 Mapping of Scientific Site V-51 Marius Hills, Project History, NASA Contract W-12, 375, TOPOCOM, July 1970

4.4.11 Mapping of Lunar Site Fra Mauro, Technical Report, ACIC April 1970

4.4.12 Mapping of Lunar Scientific Site Rima Bode II, Technical Report, ACIC, September 1970

4.4.13 Lunar Exploration Site V - 43.2 Gassendi, Project History, TOPOCOM, August 1971

4.4.14 Mapping of Apollo 16 Landing Site DESCARTES, Project History, TOPOCOM, November 1971

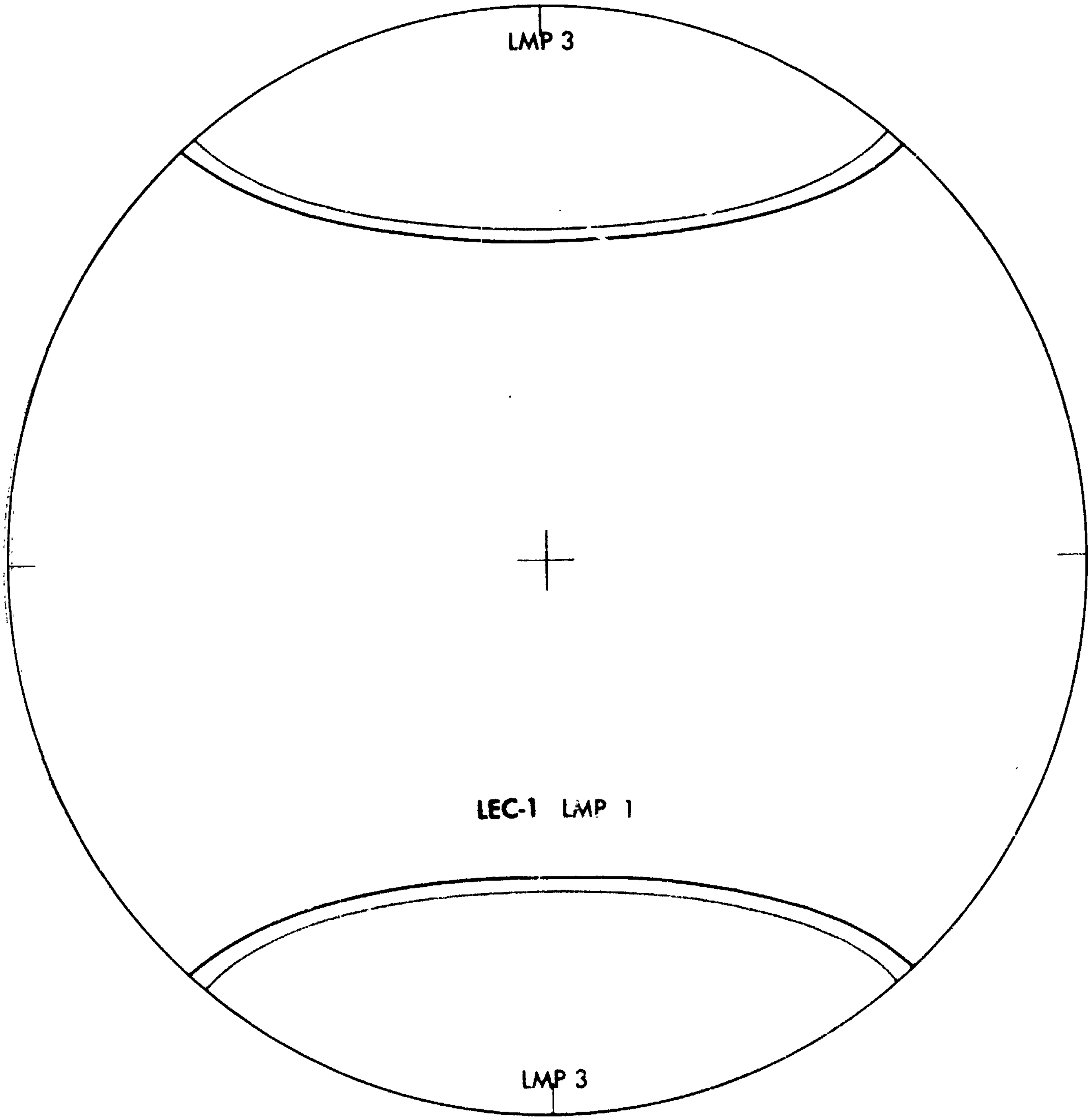
4.4.15 Mapping of the Moon, Past and Present, Z. Kopal and R. C. Calder, Vol. 50, Astrophysics & Space Science Library, 1974

4.5 MAP INDICES

INDEX NO.	DESCRIPTION
I(1)	Small Scale Earthside Maps (1:5,000,000)
I(2)	Small Scale Earthside Maps (1:2,500,000 - 1:2,750,000)
I(3)	Small Scale Earthside Mosaics (1:2,500,000)
I(4)	Small Scale Earthside Maps (1:2,000,000 - 1:2,500,000)
I(5)	Medium Scale Earthside Maps (1:500,000 - 1:1,000,000)
I(6)	Large Scale Earthside Maps (1:250,000)
I(6a)	Large Scale Earthside Maps (1:250,000)
I(7)	Large Scale Earthside Maps (1:100,000)
I(8)	Large Scale Earthside Maps (1:25,000)
I(8a)	Large Scale Earthside Maps (1:25,000 - 1:250,000)
I(9)	Ranger Lunar Maps
II(1)	Small Scale Farside Maps (1:5,000,000)
II(2)	Small Scale Farside Maps (1:2,500,000 - 1:2,750,000)
II(3)	Small Scale Farside Mosaics (1:2,500,000)
II(4)	Large Scale Farside Maps (1:250,000)

4.5 MAP INDICES

INDEX NO.	DESCRIPTION
I-1	Small Scale Earthside Maps
I-2	Small Scale Earthside Maps
I-3	Small Scale Earthside Mosaics
I-4	Small Scale Earthside Maps
I-5	Medium Scale Earthside Maps
I-6	Large Scale Earthside Maps
I-7	Large Scale Earthside Maps
I-8	Large Scale Earthside Maps
I-9	Ranger Lunar Maps
II-1	Small Scale Farside Maps
II-2	Small Scale Farside Maps
II-3	Small Scale Farside Mosaics



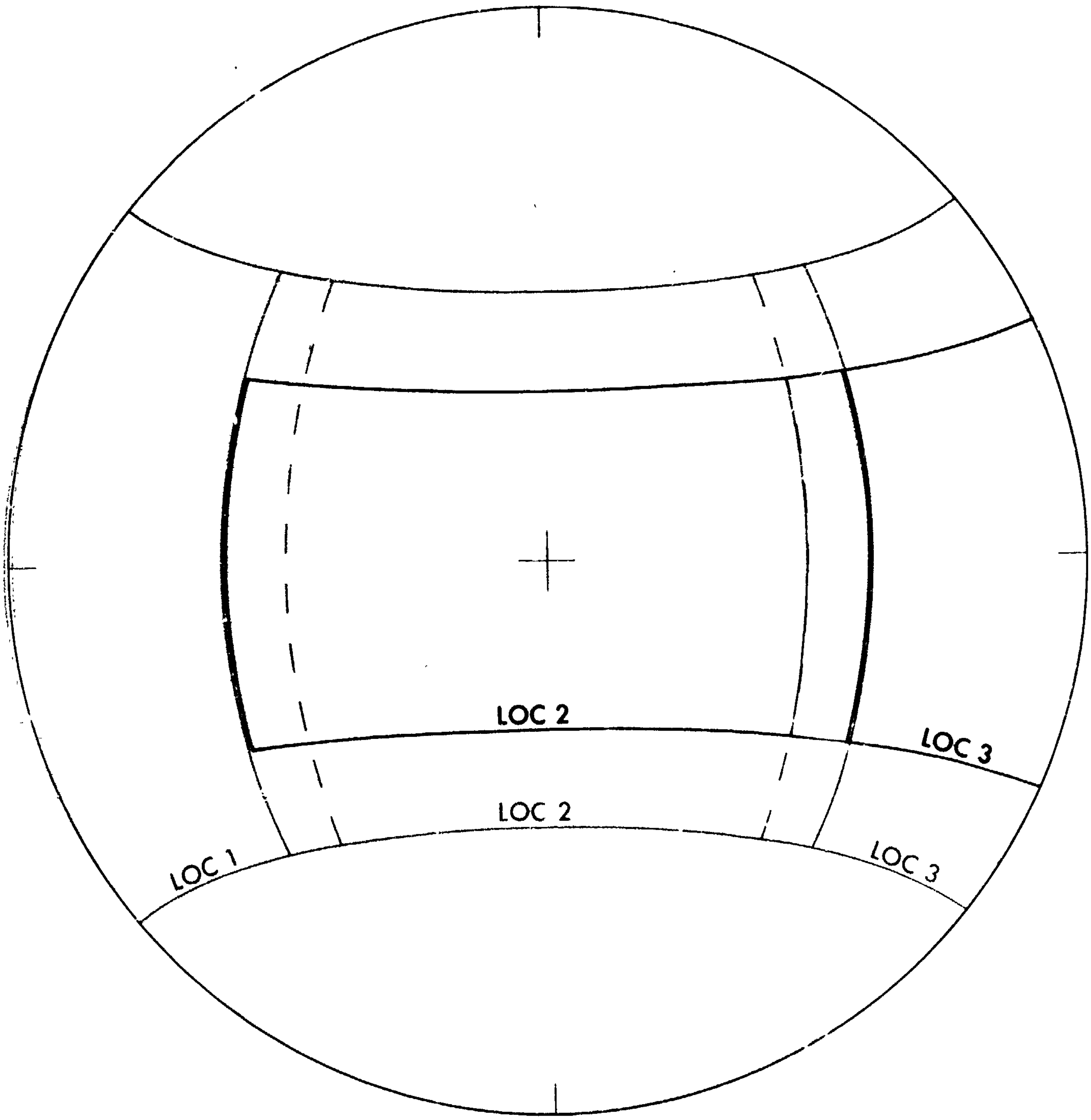
Earthside

SMALL SCALE MAPS
Scale 1:5,000,000

ACIC Lunar Chart
LMP 1:5,000,000 (1970)
ACIC Lunar Chart
LEC 1:5,000,000 (1968)

MAP INDEX NO. I (1)
Aug. 1972

REPRODUCIBILITY OF THE
ORIGINAL PAGE IS POOR

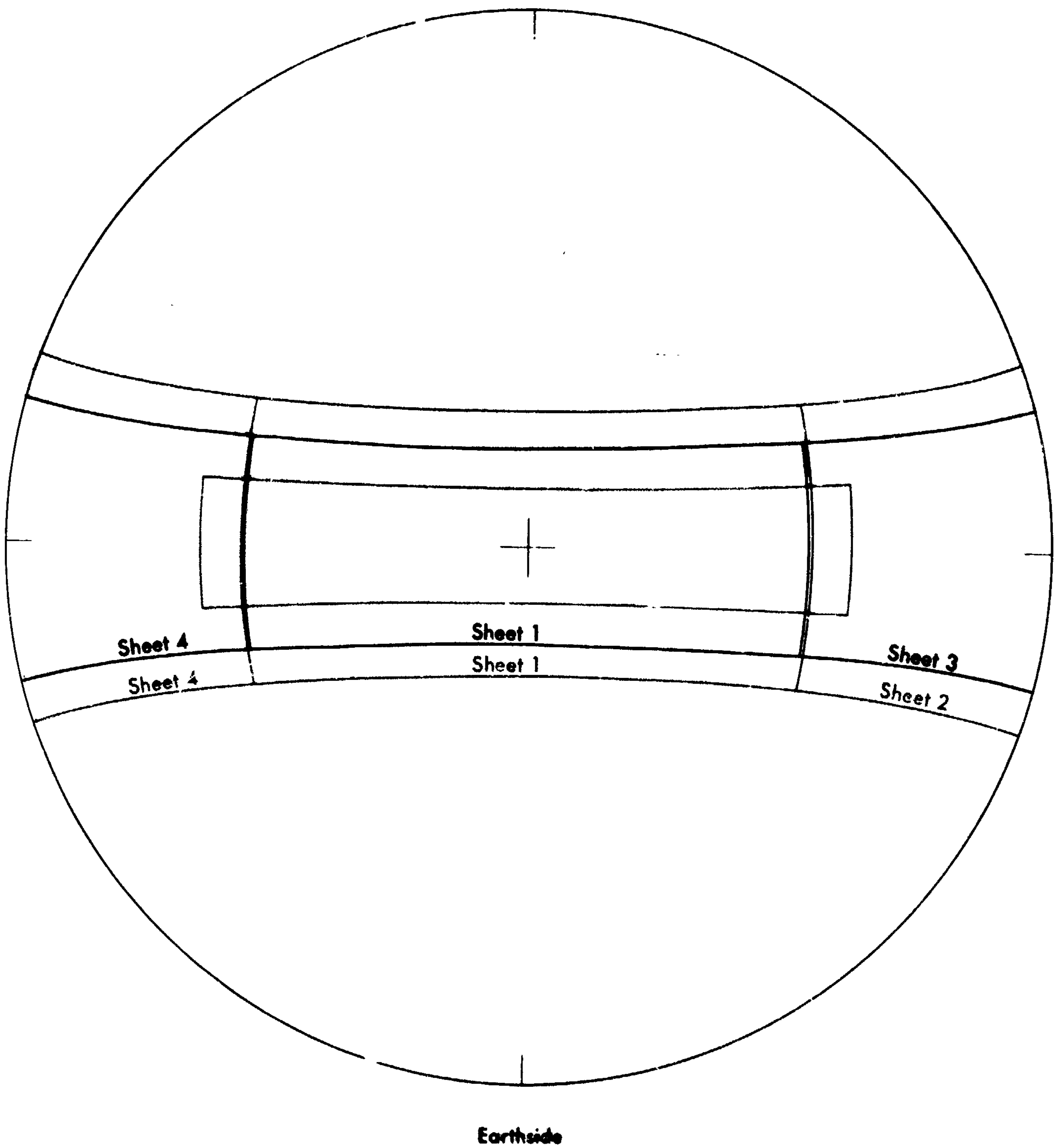


Earthside

SMALL SCALE MAPS
Scales 1:2,750,000
and 1:2,500,000

ACIC Lunar Planning Chart
LOC 1:2,750,000 (1971)
ACIC Lunar Planning Chart
LOC 1:2,500,000 (1969)

MAP INDEX NO. I (2)
Aug. 1972



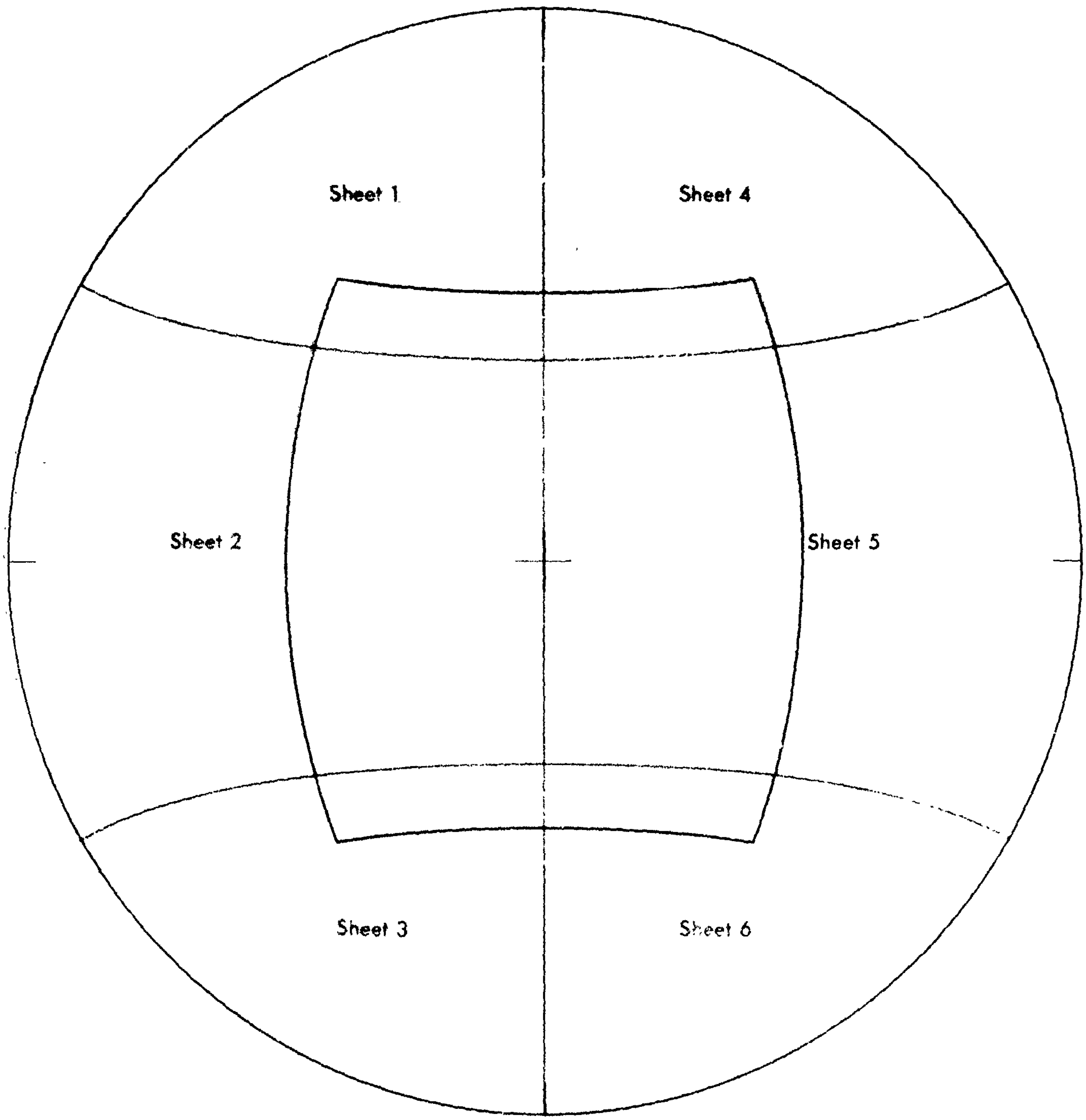
TOPOCOM Lunar Equatorial Zone Mosaic [illegible] (1969)

TOPOCOM Lunar Equatorial Zone Mosaics (19[illegible])

TOPOCOM Apollo Zone Primary Sites

SMALL SCALE MOSAICS
Scale 1:2,500,000

MAP INDEX NO. I (3)
Aug. 1972



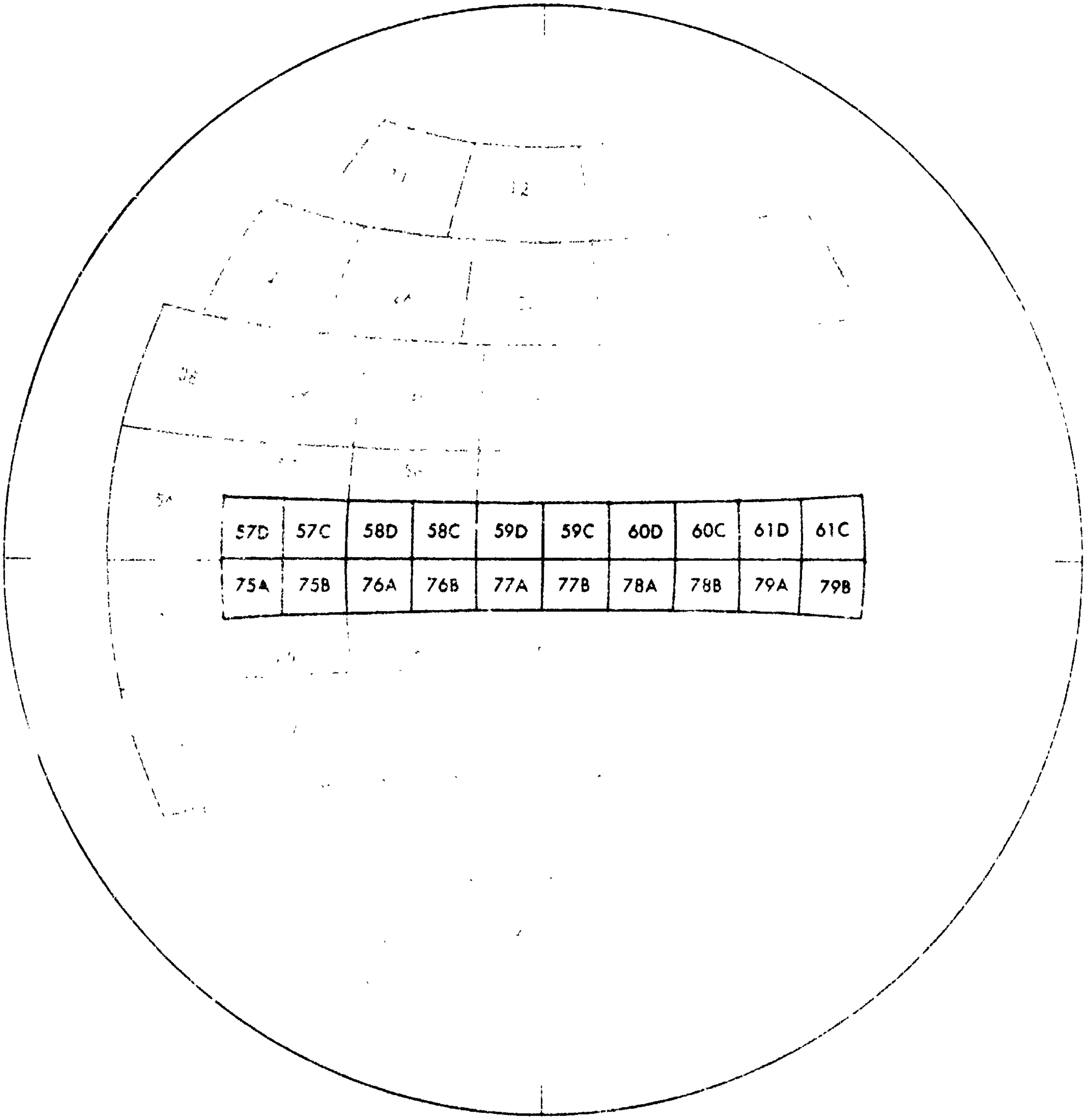
Earthside

TOPOCOM Topographic Lunar Maps
6 sheets 1:2,000,000 (1965-1967)

TOPOCOM Topographic Lunar Map
1:2,500,000 (1962)

SMALL SCALE MAPS
Scales 1:2,000,000
and 1:2,500,000

MAP INDEX NO. I (4)
Aug. 1972

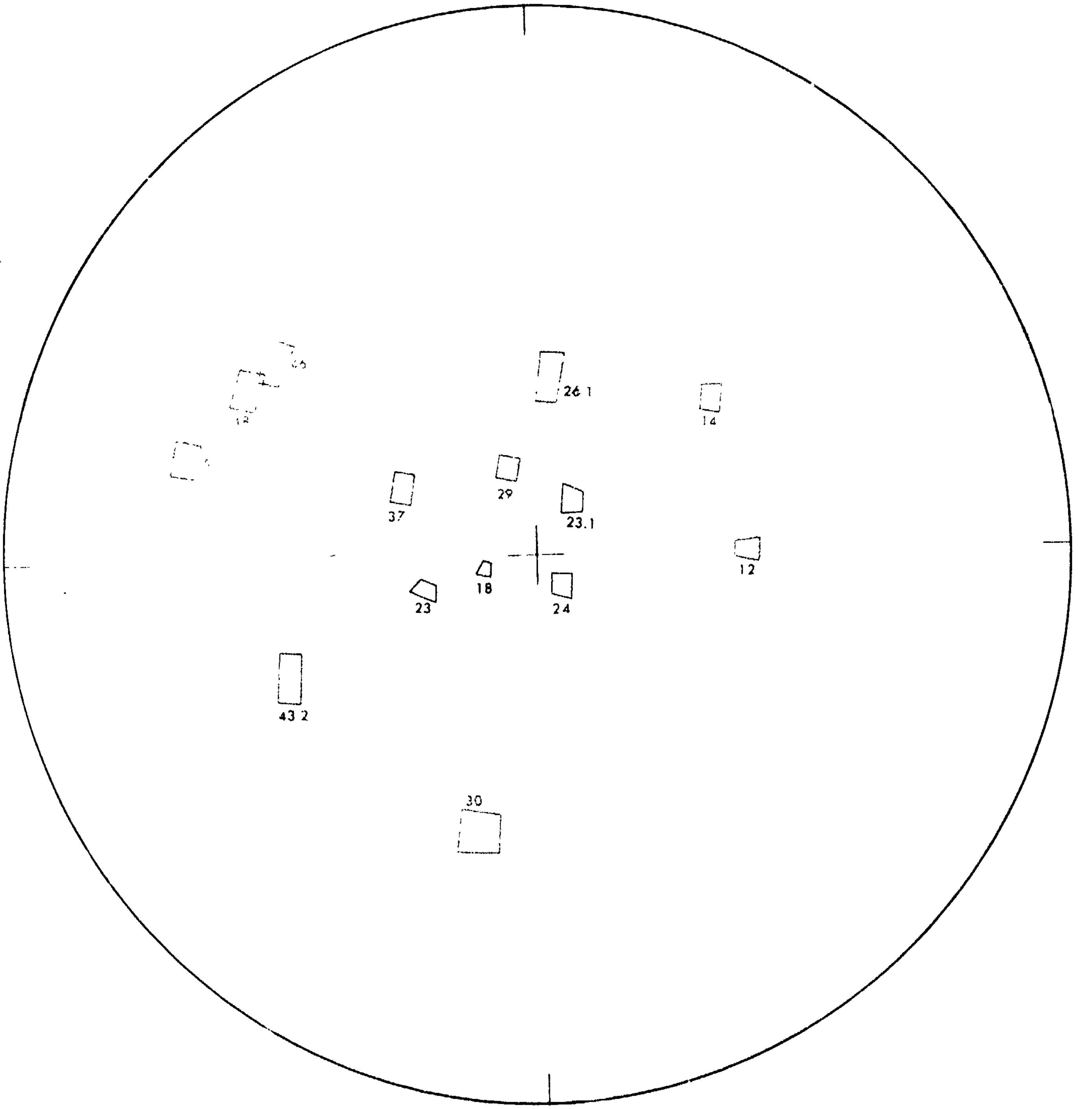


Earthside

MEDIUM SCALE MAPS
Scales 1:1,000,000
and 1:500,000

ACIC Lunar Astronautical Chart
LAC 1:1,000,000 (1962-1967)
ACIC Apollo Intermediate Chart
AIC 1:500,000 (1966-1967)

MAP INDEX NO. I (5)
Aug 1972



Earthside

Lunar Photomap, Topographic
Photomap and Topographic Map

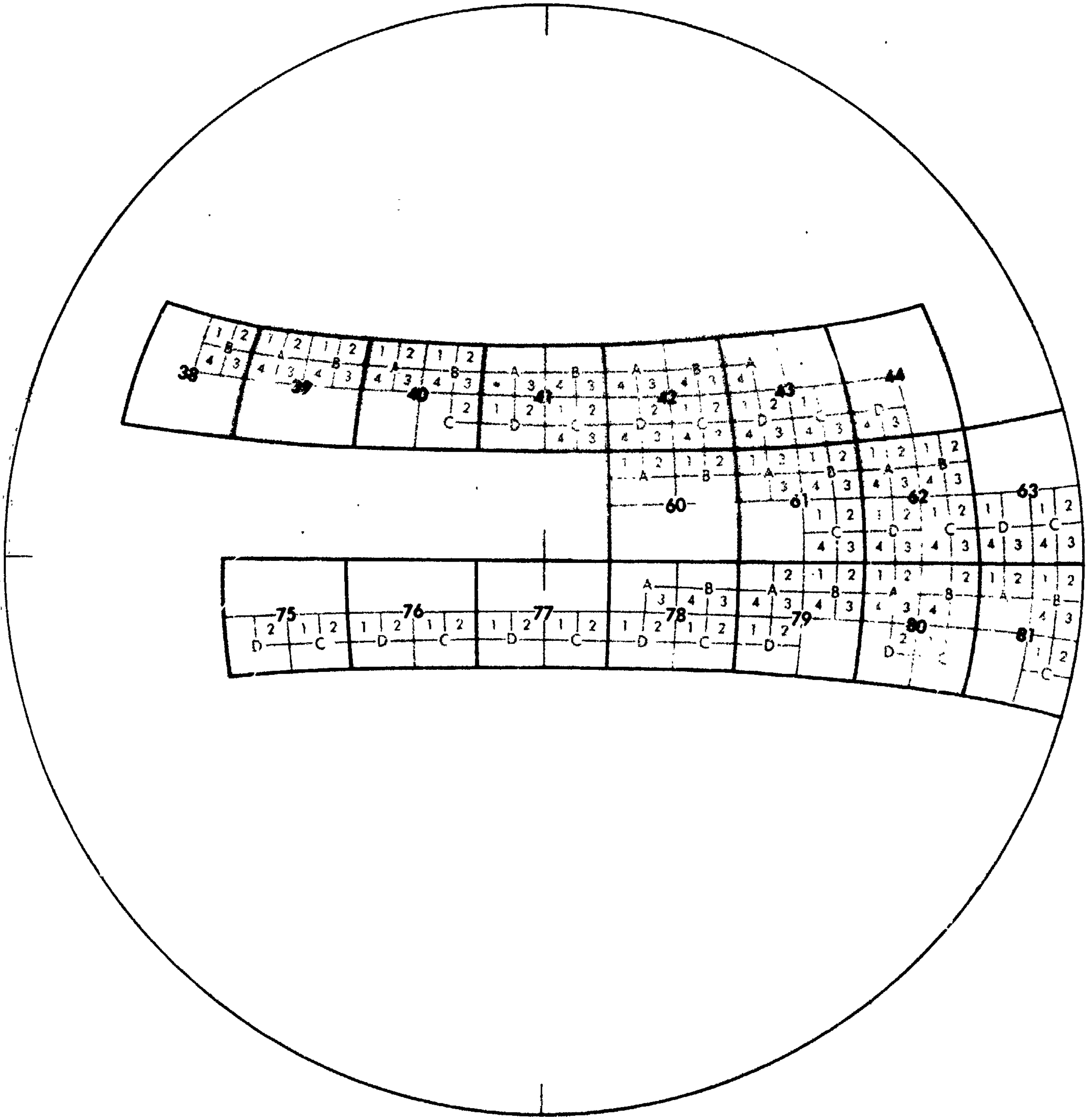
Orbiter Mission

III Site — 18

V Site — 24

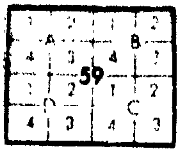
LARGE SCALE MAPS
(Photomap, Topographic Photomap,
and Topographic Map Series)
Scale 1:250,000

MAP INDEX NO. I (6)
Aug. 1972



Earthside

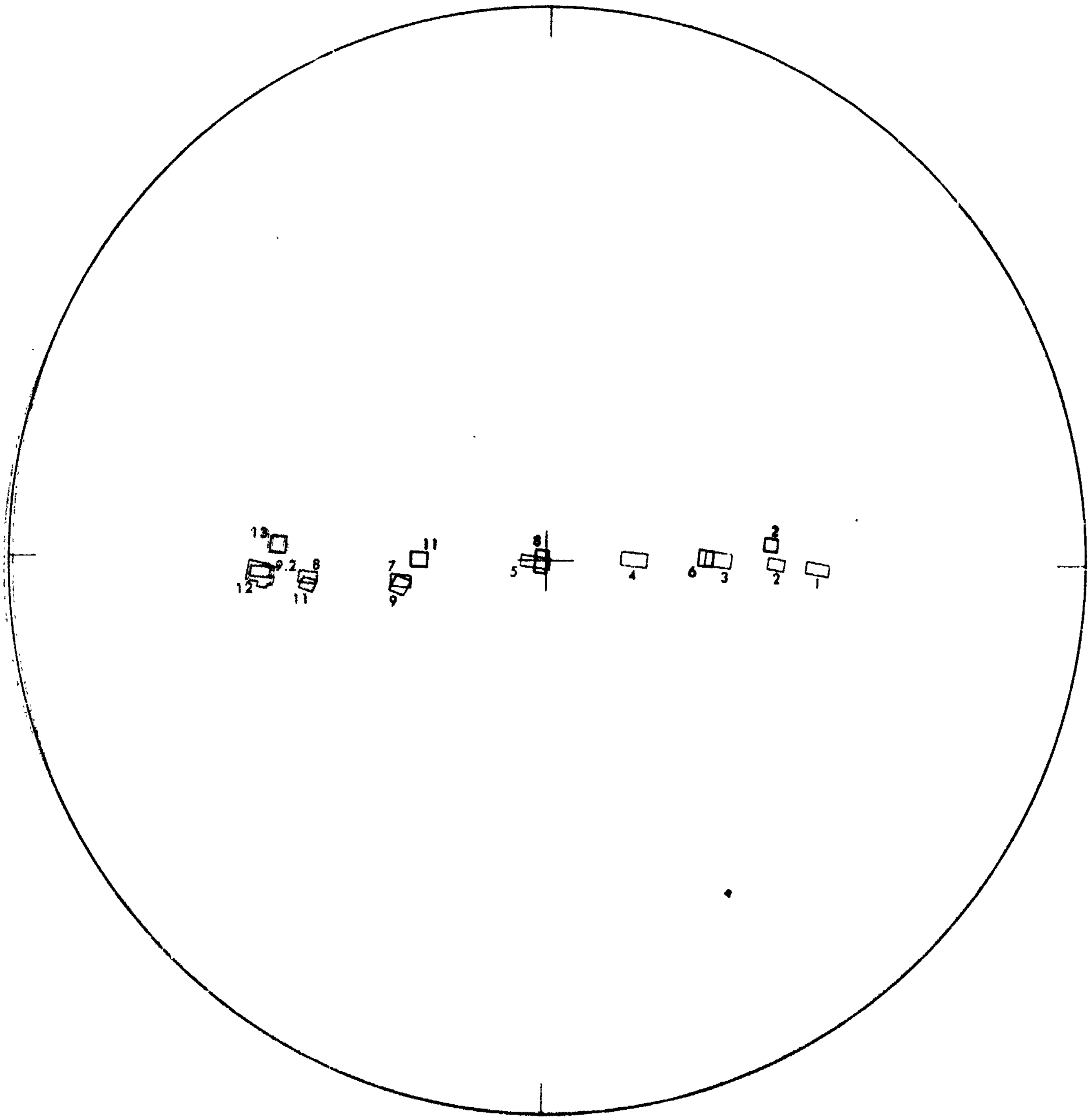
Lunar Orthophotomaps (LO) and Topographic Orthophotomaps (LTO)



LARGE SCALE MAPS
Scale 1:250,000

MAP INDEX NO. I (6a)

February 1975



Earthside

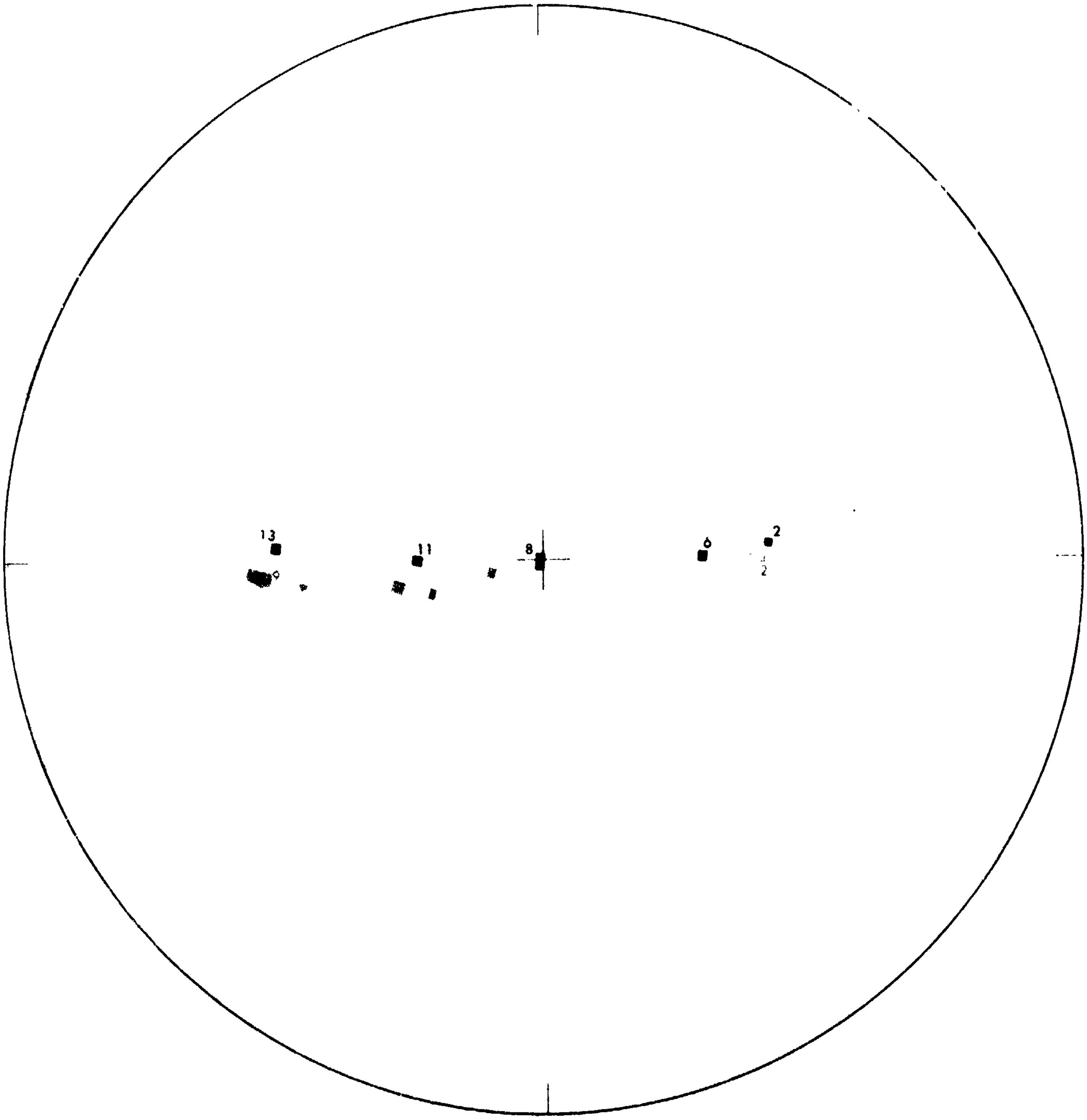
LARGE SCALE MAPS
AND PHOTOMAPS
Scale 1:100,000

Orbiter Mission

I	II	III
Site 1	Site 2	Site 9

Lunar Maps and Photomaps
OHD (1967-1968)

MAP INDEX NO. I (7)
Aug. 1972



Earthside

**LARGE SCALE MAPS
AND PHOTOMAPS
Scale 1:25,000**

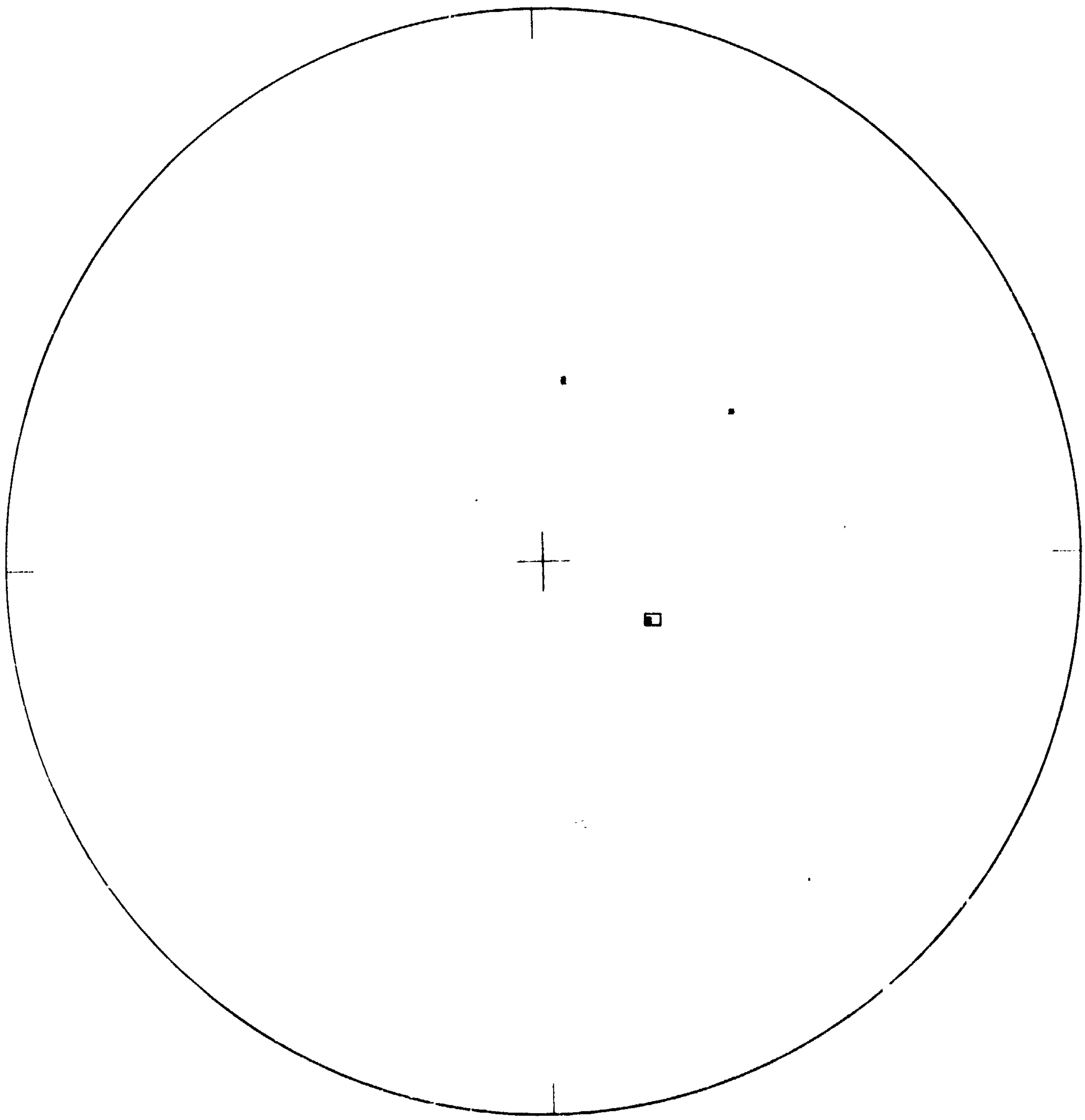
Orbiter Mission

I	II	III	V
Site	Site	Site	Site
9	2	?	12

Lunar Map and Photomap
ORB (1967-1969)

MAP INDEX NO. I (8)

Aug. 1972



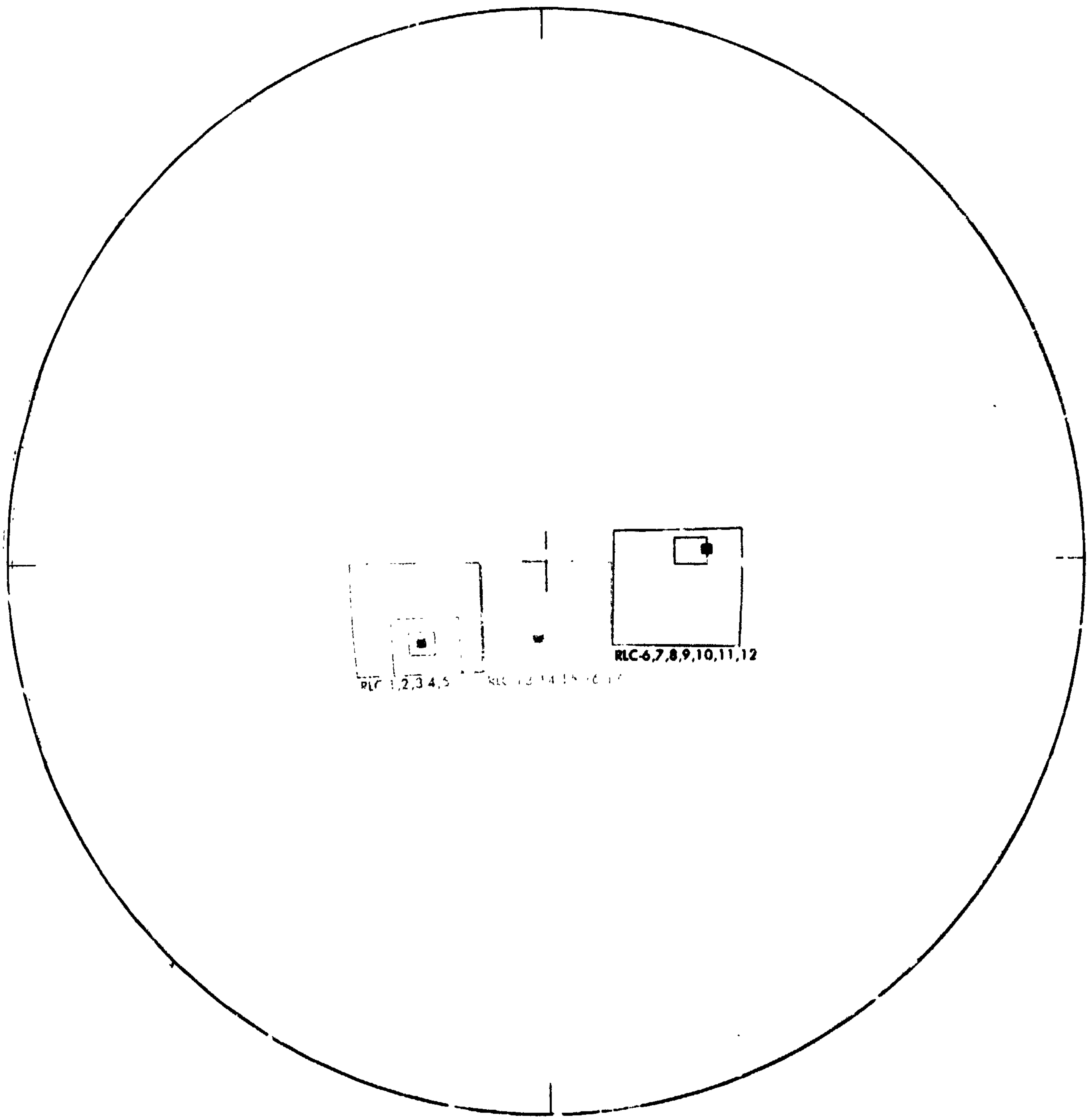
Earthside

	1:25,000	1:50,000	1:100,000	1:250,000
Rima Hadley				
Descartes				
Taurus Littrow				

LARGE SCALE MAPS
Scale 1:25,000 - 1:250,000

MAP INDEX NO I (8a)

February 1975



Earthside

ACIC Ranger VII Lunar Charts (1964)

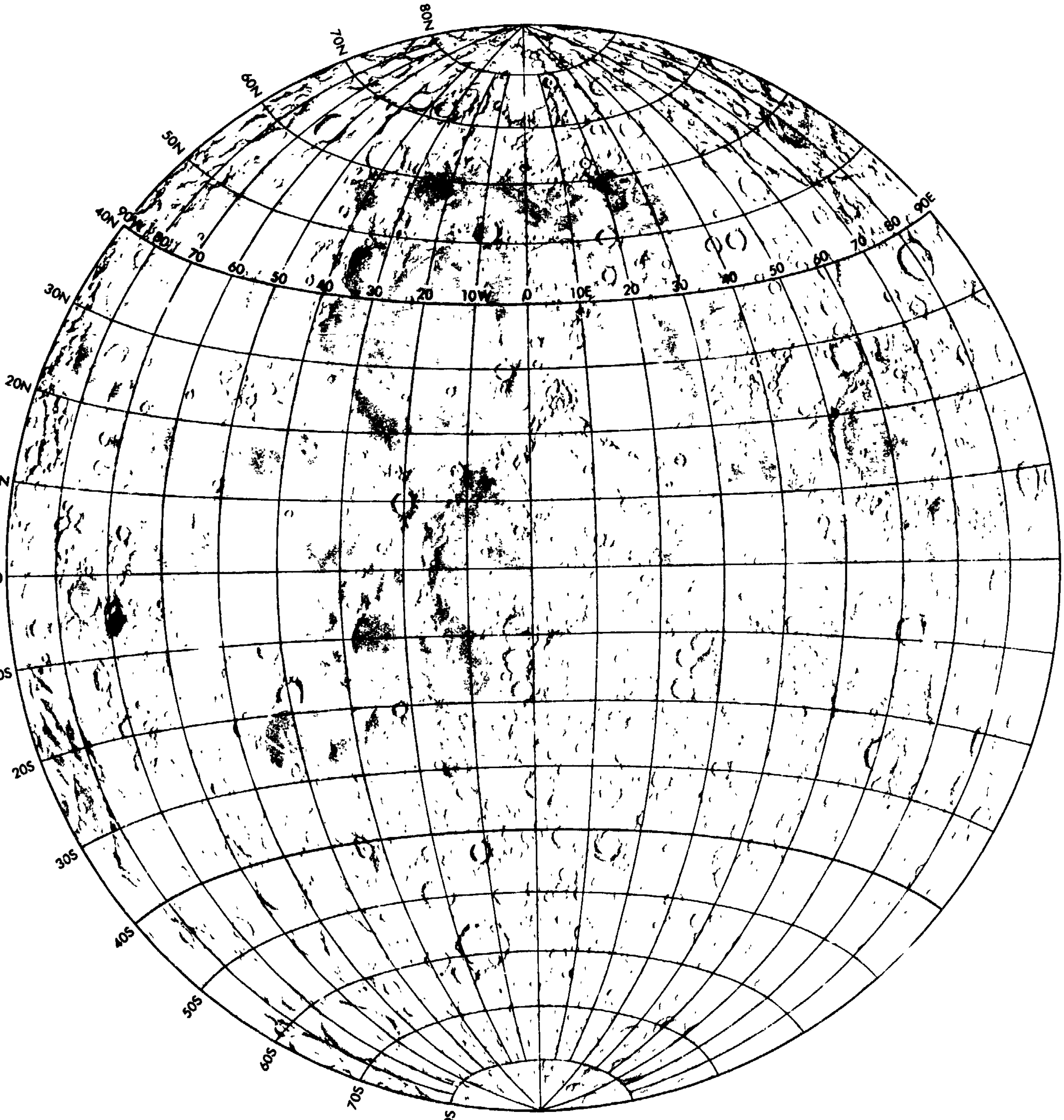
ACIC Ranger VIII Lunar Charts (1966)

ACIC Ranger IX Lunar Charts (1966)

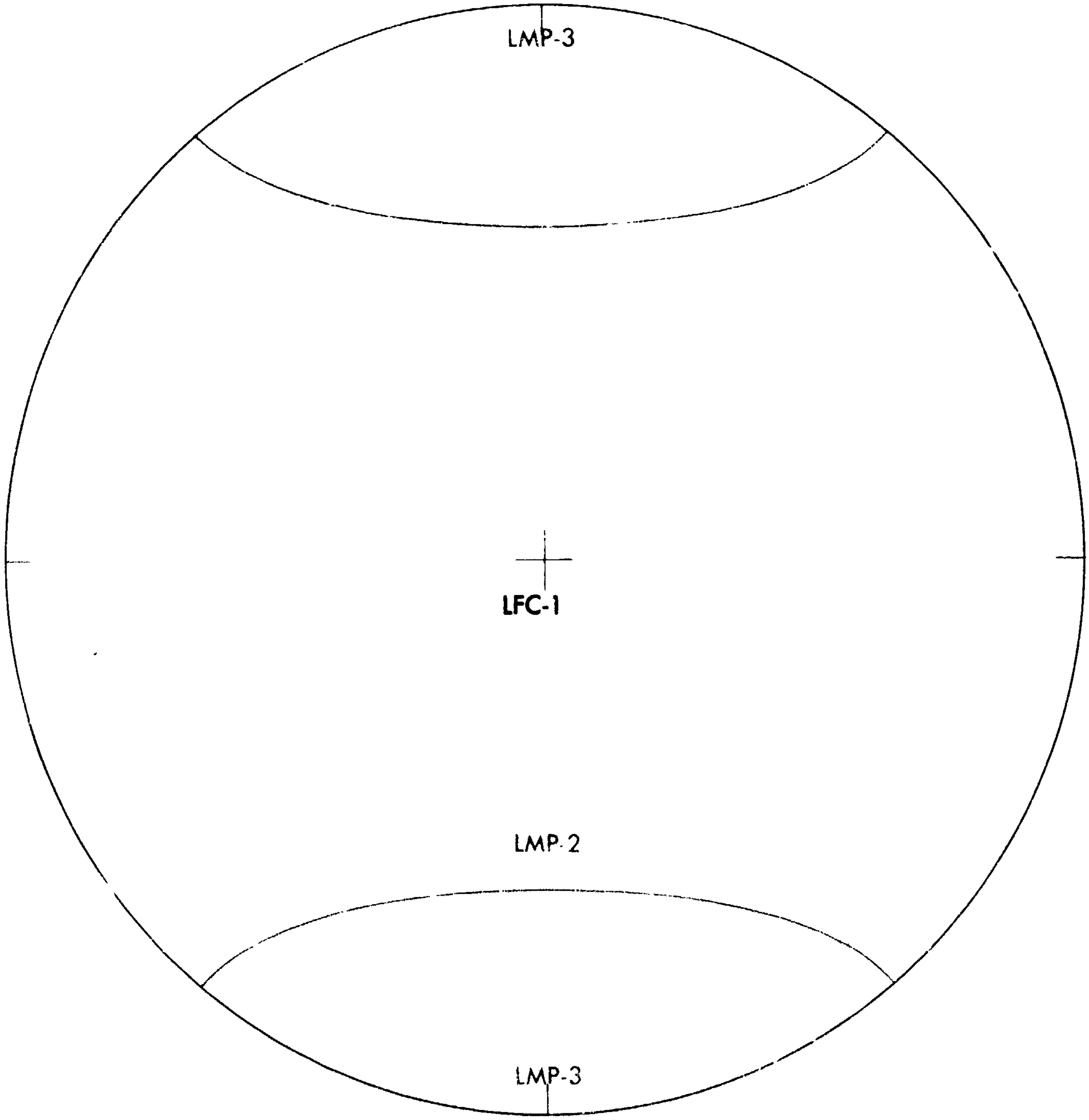
RANGER LUNAR MAPS
Ascending Scales
1:1,000,000 and larger

MAP INDEX NO. I (9)
Aug. 197[illegible]

BASE MAP COURTESY OF
NATIONAL GEOGRAPHIC SOCIETY



Earthside



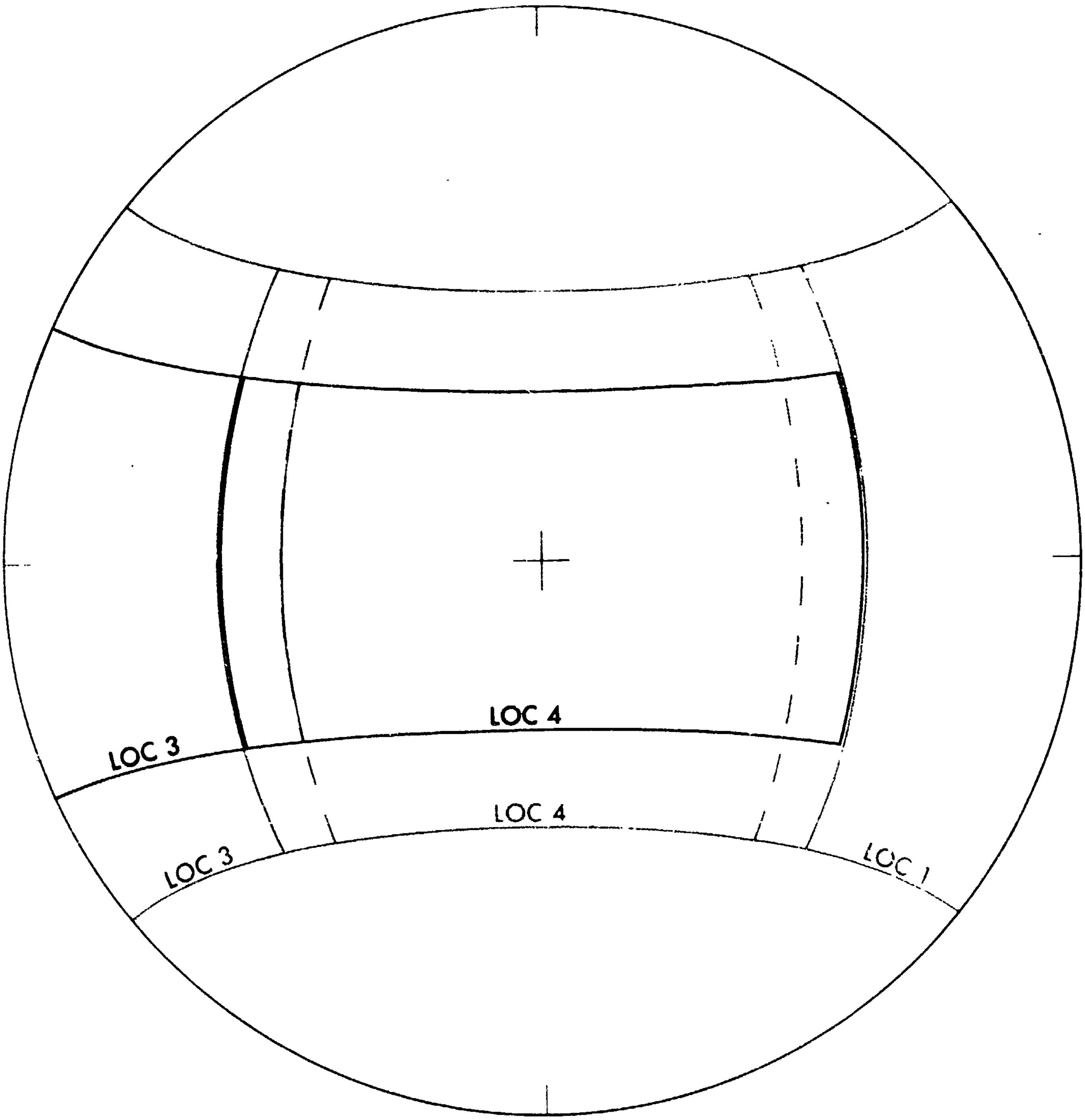
Farside

SMALL SCALE MAPS
Scale 1:5,000,000

ACIC Lunar Chart
LMP 1:5,000,000 (1970)

ACIC Lunar Chart
LFC-1 1:5,000,000 (1967)

MAP INDEX NO. II (1)
Aug. 1972



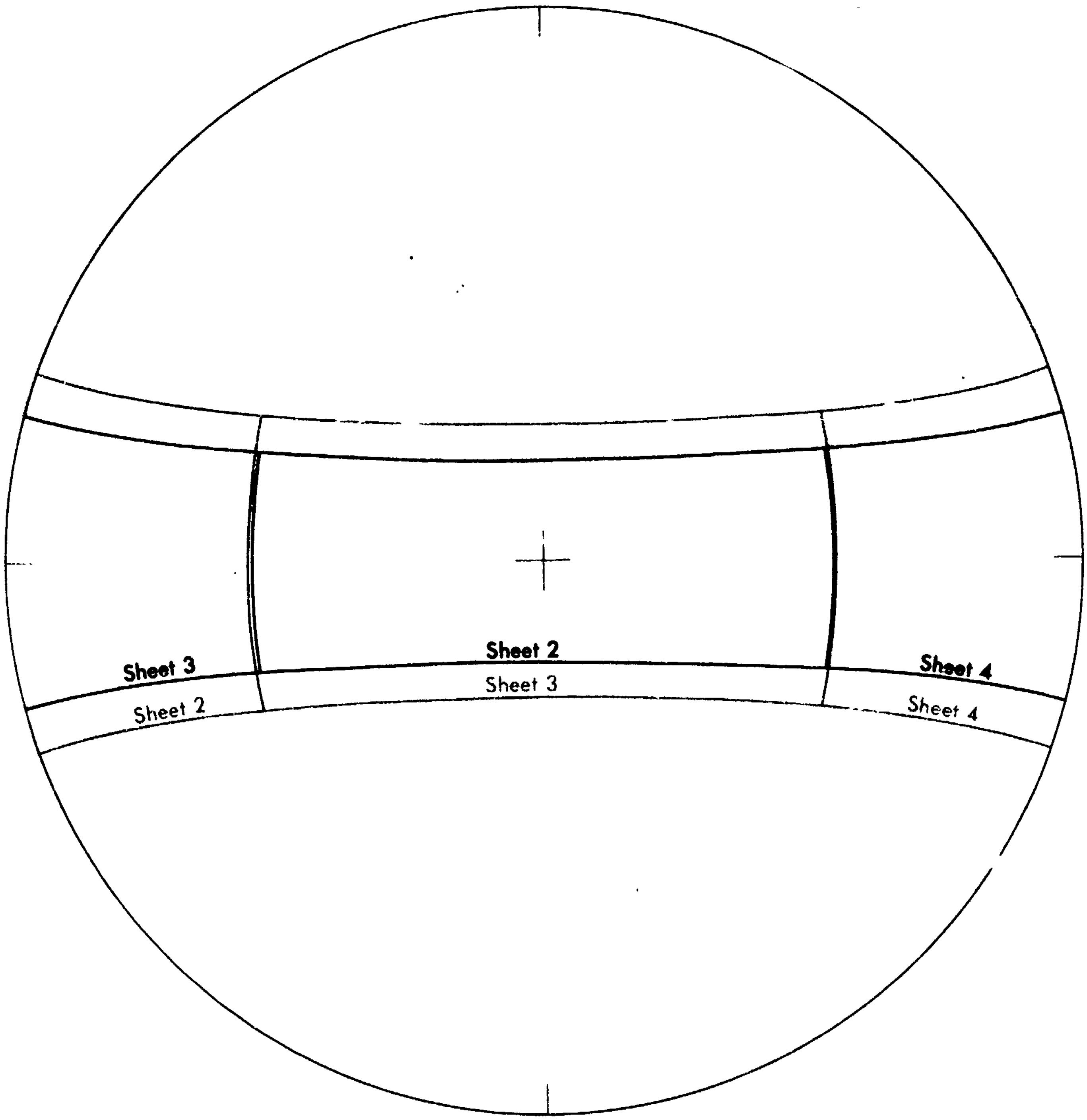
Farside

ACIC Lunar Planning Chart
LOC 1:2,750,000 (1971)

ACIC Lunar Planning Chart
LOC 1:2,500,000 (1969)

SMALL SCALE MAPS
Scales 1:2,750,000
and 1:2,500,000

MAP INDEX NO. II (2)
Aug. 1972

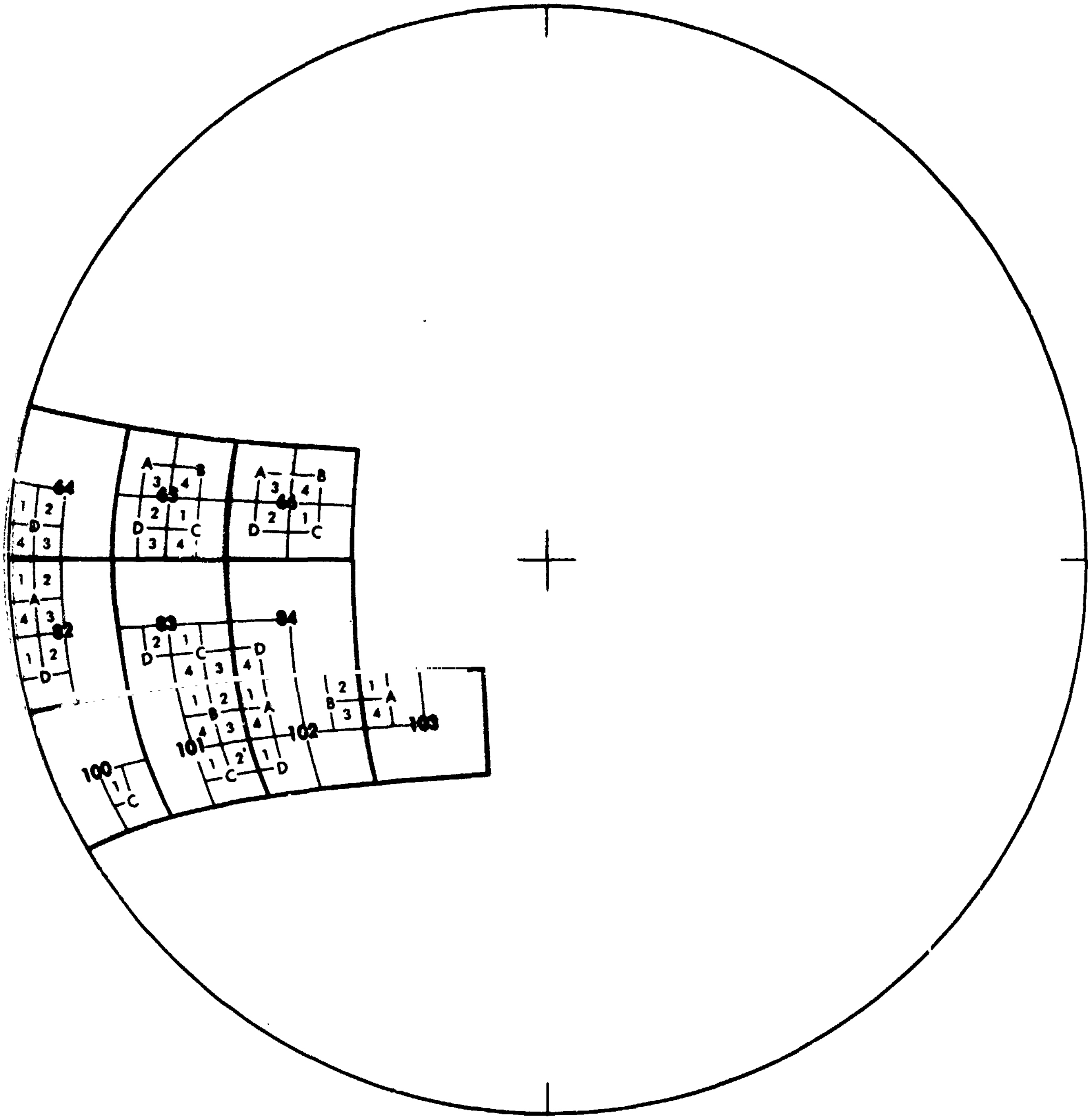


Farside

TOPOCOM Lunar Equatorial Zone
Mosaic LEMC (1969)
TOPOCOM Lunar Equatorial Zone
Mosaics (1968)

SMALL SCALE MOSAICS
Scale 1:2,300,000

MAP INDEX NO. II (3)
Aug. 1972



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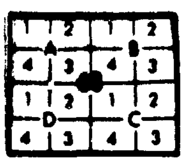
LARGE SCALE MAPS
Scale 1:250,000

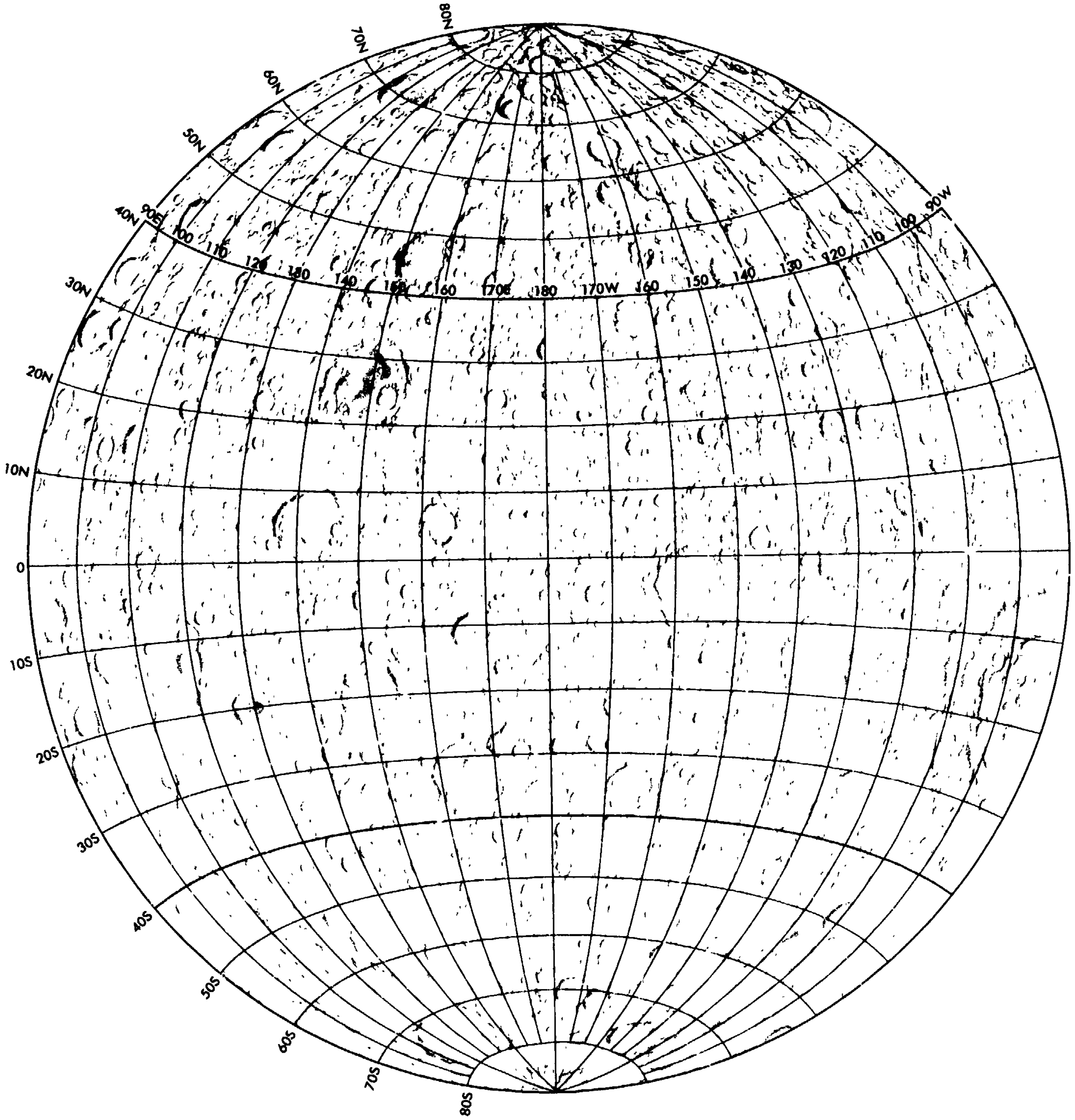
Lunar Orthophotomaps (LO)
and Topographic Orthophotomaps (LTO)



MAP INDEX NO. II (4)

February 1975

BASE MAP COURTESY OF
NATIONAL GEOGRAPHIC SOCIETY



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