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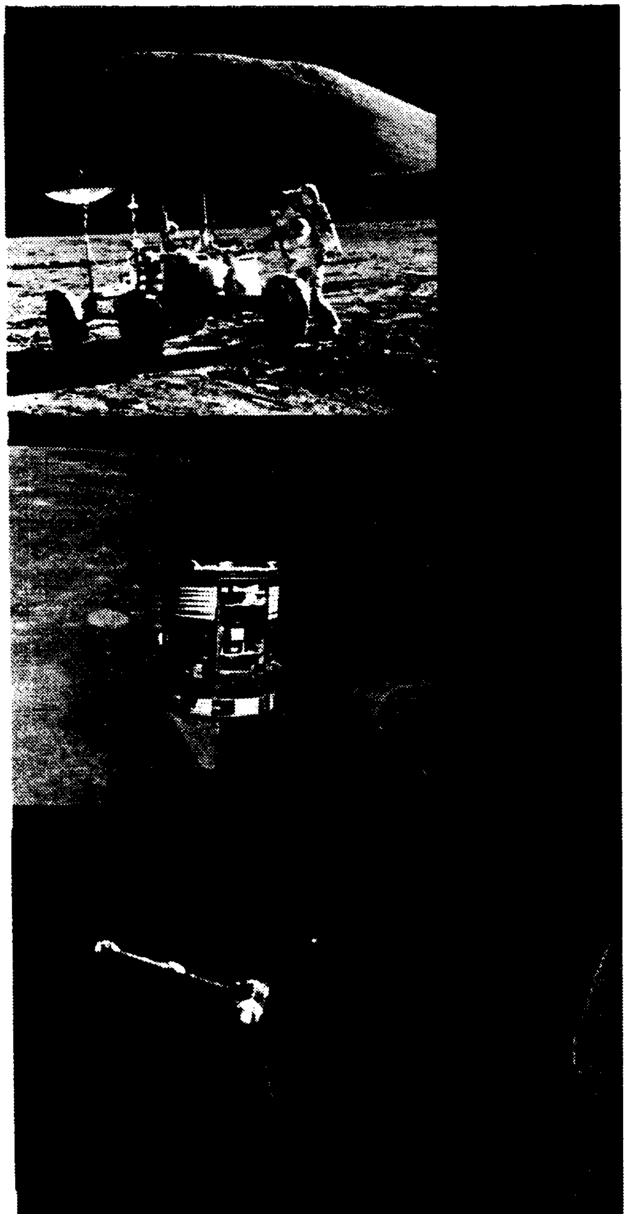
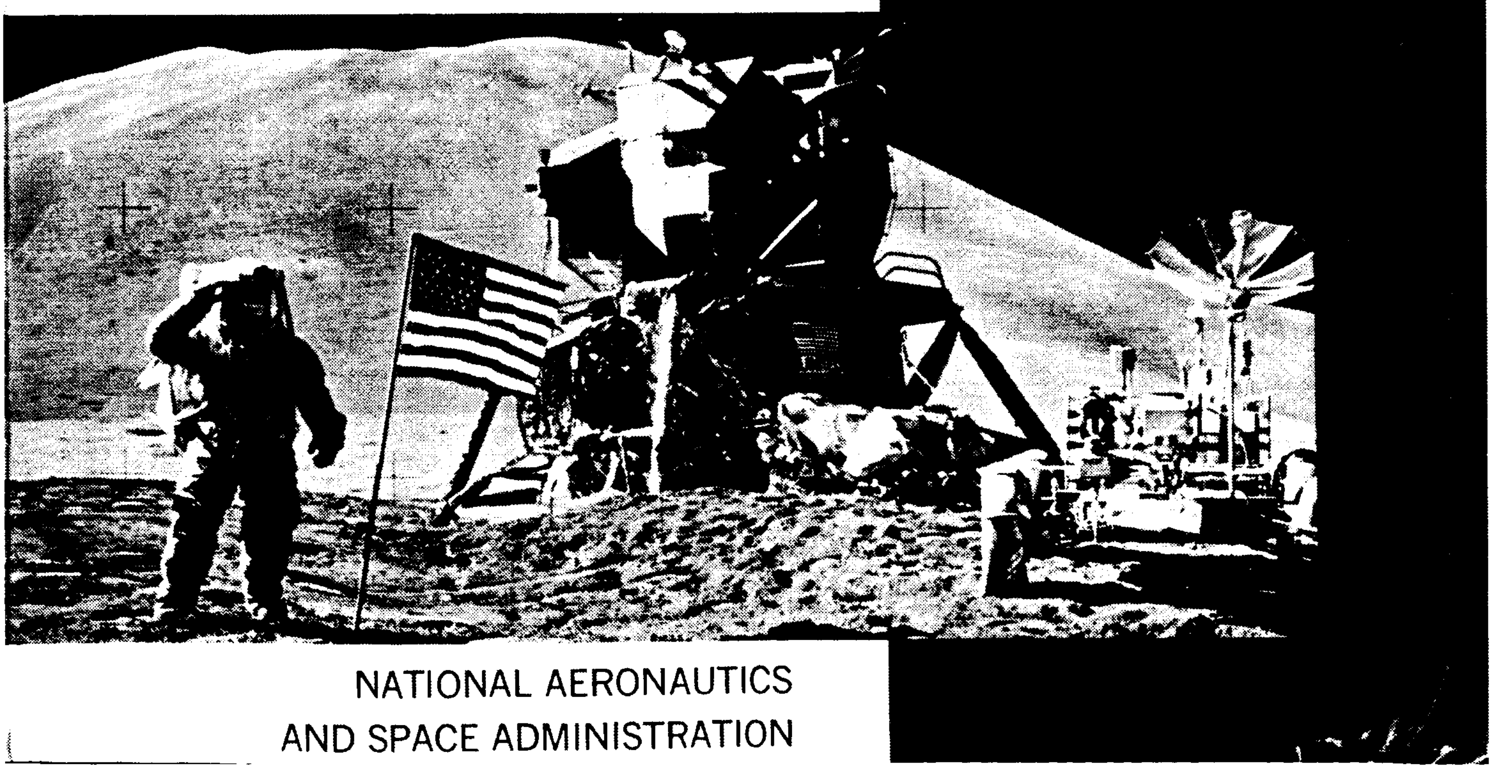
APOLLO 15

Preliminary Science Report





NATIONAL AERONAUTICS
AND SPACE ADMINISTRATION

12. Suprathermal Ion Detector Experiment (Lunar Ionosphere Detector)

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The suprathermal ion detector experiment (SIDE), part of the Apollo lunar surface experiments package (ALSEP), is designed to provide information on the energy and mass spectra of the positive ions close to the lunar surface (the lunar exosphere). These ions can be classified into two groups: (1) those that result from the ionization of gases generated on the Moon by natural and manmade sources, and (2) those that arrive from sources beyond the near-Moon environment.

The ions generated on the Moon are of intense interest because possible sources of these ions are sporadic outgassing from volcanic or seismic activity, gases from a residual primordial atmosphere of heavy gases, evaporation of solar-wind gases accreted on the lunar surface, and exhaust gases from the lunar module (LM) descent and ascent engines and from the astronauts' portable life-support equipment.

An example of the significant results of this experiment is the recent report[1] of the detection of water vapor in the lunar exosphere by the Apollo 14 SIDE. Water from some unknown depth below the surface is believed to be liberated by seismic activity, after which it vaporizes instantly upon exposure to the vacuum of the lunar atmosphere. The vapor is then dispersed over a wide area; some fraction of it becomes ionized and is subsequently detected by the SIDE.

In addition, evidence for the operation of a prompt ionization and acceleration mechanism operating in the lunar exosphere and a preliminary measurement of the decay time for the heavier components of the Apollo exhaust gases have been presented in reference 12-1, based on data from the Apollo 12 and 14 SIDE instruments. Electric and magnetic fields near the lunar surface can be studied by observing their effects on the motions and energies of the ions after they are generated. The network of three SIDE instruments (Apollo 12, 14, and 15) now operating on the Moon allows more precise determination of the dimensions and motions of ion clouds moving across the lunar surface. In this section, the instruments at these different sites are used to follow the motions of ions apparently resulting from two meteoroid-impact events, from the LM-ascent-stage impact, and from short-duration events occurring during the lunar night.

The ions from distant sources include those from the solar wind and also those which are part of the magnetosphere of the Earth. The magnetic field of the Earth deflects the incoming solar-wind ions so that they do not reach the surface. Instead, these ions undergo complex motions in the magnetosphere, which surrounds the Earth and extends to great distances in the direction away from the Sun (the magnetospheric tail). Because the Moon does not have a strong magnetic field, the solar wind can impinge directly on the lunar surface. This plasma interaction between the solar wind and the solid Moon can, therefore, be studied by means of the instrumentation on the lunar surface. In addition, the motions of ions in the magnetosphere can be investigated during those periods when the Moon passes through the magnetospheric tail of the Earth. In this report, the highly directional flow of energetic ions down the magnetosheath (or boundary region of the magneto-

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[1] J. W. Freeman, Jr., paper presented at the Lunar Geophysics Conference, Houston, Tex., Oct. 18-21, 1971.

sphere) is described by using the three different look directions of the three SIDE instruments. The effects of the interaction of the LM ascent-engine exhaust with the magnetosheath ions observed at the Apollo 15 site are also discussed.

The principal contributions to the SIDE scientific objectives reported in this paper are as follows.

(1) Multiple-site observations of the apparent movement of an ion source presumed to be a neutral gas cloud resulting from a meteoroid impact
(2) Observation of the complicated ion event related to the Apollo 15 LM impact
(3) Observation of a sharp decrease in the magnetosheath fluxes at the time of LM lift-off
(4) Three-directional observations of the 500- to 1000-eV ions streaming down the magnetosheath
(5) Further observations of short-duration energetic-ion events occurring during the lunar night

INSTRUMENT

The Apollo 15 SIDE instrument is basically identical to those flown on the Apollo 12 (ref. 12-2) and 14 (ref. 12-3) missions. The only major difference is in the mass ranges covered by the three instruments. However, the Apollo 15 instrument is completely described herein.

Description

The SIDE consists of two positive-ion detectors. The first of these, the mass analyzer detector, is provided with a Wien velocity filter (crossed electric and magnetic fields) and a curved-plate electrostatic energy-per-unit-charge filter in tandem in the ion flight path. The requirement that the detected ion must pass through both filters allows a determination of the mass per unit charge. The ion sensor itself is a channel electron multiplier operated as an ion counter that yields saturated pulses for each input ion. The second detector, the total ion detector, uses only a curved-plate electrostatic energy-per-unit-charge filter. Again, the ion sensor itself is a channel electron multiplier operated as an ion counter. Both channel electron multipliers are biased with the input ends at -3.5 kV, thereby providing a postanalysis acceleration to boost the positive-ion energies to yield high detection efficiencies. The general detector concept is illustrated in figure 12-1; figure 12-2 is a cutaway drawing that illustrates the location of the filter elements and the channel electron multipliers.

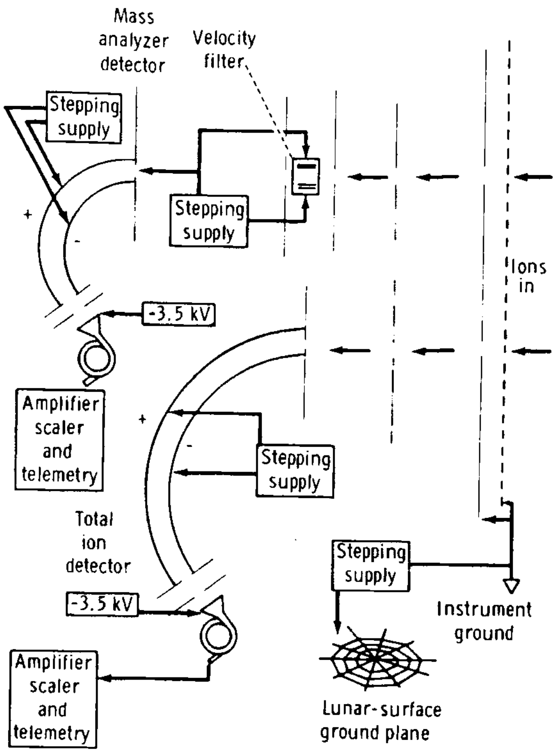

FIGURE 12-1.–Schematic diagram of the SIDE.

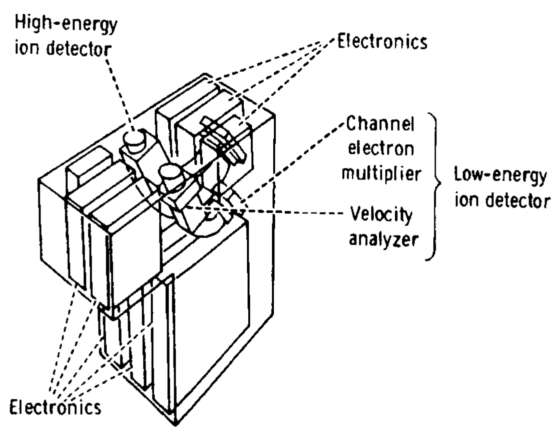

FIGURE 12-2.–Cutaway drawing showing the interior of the SIDE.

A primary objective of the experiment is to provide a measurement of the approximate mass-per-unit-charge spectrum of the positive ions near the lunar surface as a function of energy for ions from approximately 50 eV down to near-thermal energies.

Therefore, the mass analyzer detector measures mass spectra at six energy levels: 48.6, 16.2, 5.4, 1.8, 0.6, and 0.2 eV. Only the two highest energy levels of the mass analyzer detector were well calibrated in the laboratory, although data from the other levels are still useful. For the Apollo 15 mass analyzer detector, 20 mass channels span the mass spectrum from 1 to approximately 90 atomic-mass units per charge (amu/Q). The total ion detector measures the differential positive-ion energy spectrum (regardless of mass) from 3500 eV down to 10 eV in 20 energy steps.

To compensate for the possibly large (tens of volts) lunar-surface electric potential, a wire screen is deployed on the lunar surface beneath the SIDE. This screen is connected to one side of a stepped voltage supply, the other side of which is connected to the internal ground of the detector and to a grounded grid mounted immediately above the instrument and in front of the ion entrance apertures (fig. 12-1). The stepped voltage is advanced only after a complete energy and mass scan of the mass analyzer detector (i.e., every 2.58 min). The voltage supply is programed to step through the following voltages: 0, 0.6, 1.2, 1.8, 2.4, 3.6, 5.4, 7.8, 10.2, 16.2, 19.8, 27.6, 0, -0.6, -1.2, -1.8, -2.4, -3.6, -5.4, -7.8, -10.2, -16.2, -19.8, and -27.6. This stepped supply and the ground screen may function in either of two ways. If the lunar-surface potential is large and positive, the stepped supply, when on the appropriate step, may counteract the effect of the lunar-surface potential and thereby allow low-energy ions to reach the instrument with their intrinsic energies. However, if the lunar-surface potential is near zero, then on those voltage steps that match or nearly match the energy level of the mass analyzer detector or the total ion detector (1.2, 5.4, etc.), thermal ions may be accelerated into the SIDE at energies optimum for detection. The success of this method depends on the Debye length and on the extent to which the ground-screen potential approximates that of the lunar surface. It is not yet possible to assess either of these factors; however, the data from the Apollo 12 and 14 ALSEP instruments indicate that the ground-screen voltage often has little influence on the response of the instrument to the incoming ions.

The SIDE is shown deployed on the lunar surface in figure 12-3. The experiment is deployed approximately 15 m northeast of the ALSEP central station. The top surface stands 0.5 m above the lunar surface. The instrument is tilted 26° from vertical toward the south so that the sensor look directions include the ecliptic plane; the look axes are directed 15° to the east. The field of view of each sensor is roughly a square solid angle, 6° on a side. The sensitivities of the total ion detector and of the mass analyzer detector are approximately 5×10^{17} and 10^{17} counts/sec/A of entering ion flux, respectively. The look directions of the Apollo 12, 14, and 15

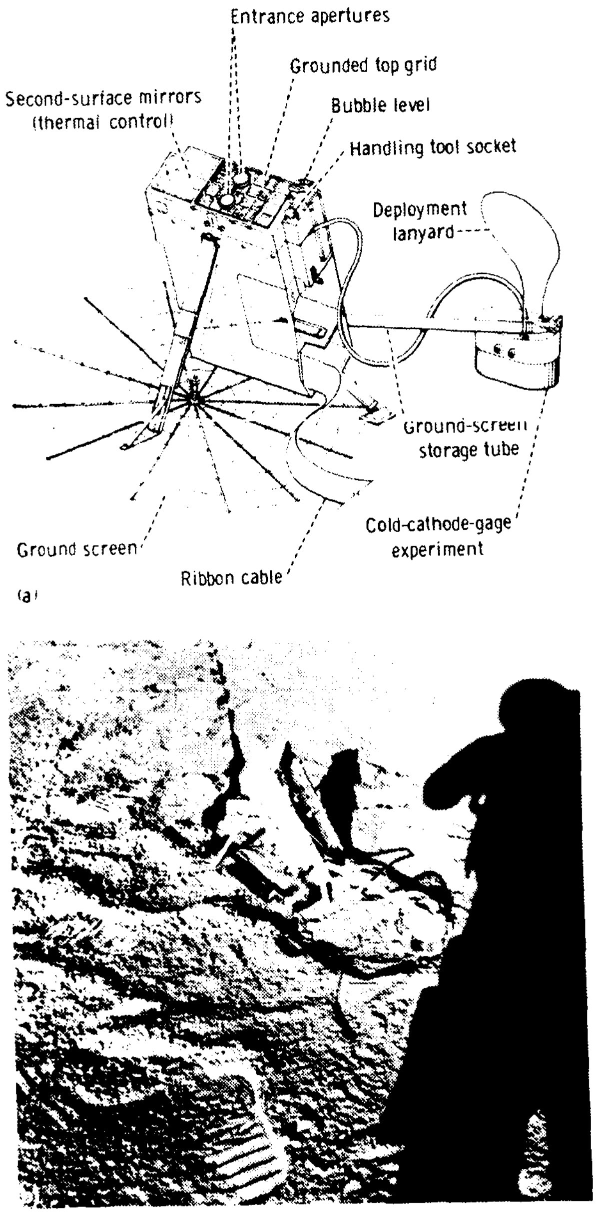

FIGURE 12-3.–The SIDE as deployed on the Moon. (a) External diagram. (b) NASA photograph AS15-86-11596.

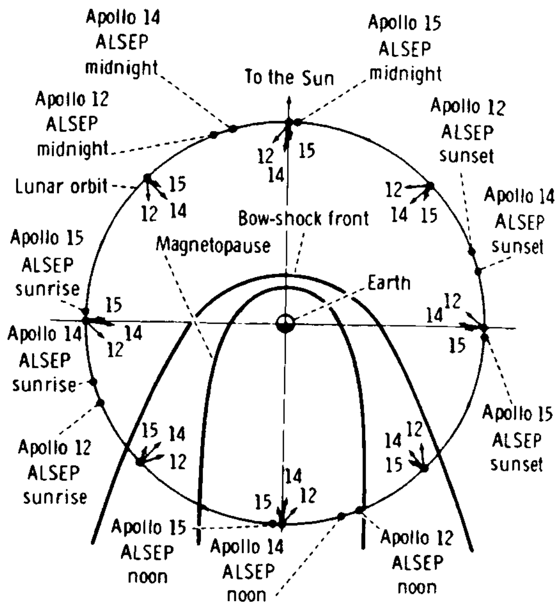

FIGURE 12-4.–The look directions of the Apollo 12, 14, and 15 SIDE instruments at various points along the lunar orbit. (The diameter of the Earth is not drawn to scale.)

instruments are shown in figure 12-4 in an Earth-Sun coordinate system at various points along the lunar orbit. As shown in the figure, the three instruments have look directions that cover a wide range of angles and thus allow study of the directional characteristics of the fluxes of ions streaming down the magnetosheath region into the tail of the magnetosphere of the Earth. Furthermore, it is possible to monitor the ion fluxes on both sides of the magnetospheric tail to check for asymmetry in the flow patterns.

Performance

At the time of preparation of this report, the operation of the SIDE and the associated cold-cathode-gage-experiment (CCGE) electronics continued to be excellent; all temperatures and voltages were nominal. The high voltages within the instrument have been commanded off for the periods of higher instrument temperature (up to ~353 K), centered on local noon, to allow the instrument to outgas without danger to the electronic components. The high voltages were not operated when the instrument temperature was greater than 310 K on the lunar day of deployment. They were operated the following lunar day up to 323 K in the morning and from 328 K down in the afternoon; no problems arose. Present plans are to increase the operating temperature limit by 10 K each successive lunar day until full-time operation is reached. The background counting rates have been quite low, well under 1 count/sec even at an internal temperature of 328 K.

RESULTS

Apollo 15 LM Ascent

The Apollo 15 SIDE measured the differential fluxes of magnetosheath ions during the ascent of the Apollo 15 LM. The expanding cloud of LM exhaust gas caused large changes in these fluxes. Before ascent, the magnetosheath ion energy spectrum was generally peaked near 1 keV, with fluxes at 3.5 keV smaller by a factor of 100 and negligible fluxes of ions with energy below 100 eV. As shown in figure 12-5, after LM ascent, the magnetosheath ion fluxes were abruptly reduced by as much as a factor of 100, and the differential energy spectrum was greatly distorted. The integral fluxes between 17:12 and 17:16 G.m.t. are probably unreliable because the fluxes are changing significantly in the time required to accumulate an integral spectrum measurement (13.3 sec). Consequently, the flux reduction and spectrum distortion are best seen in the differential flux data. Full recovery of the fluxes to preascent intensities was not attained until approximately 8 min after ascent. For approximately 5 min (starting 2.5 min after ascent), the mass analyzer detected fluxes of 48.6-eV ions with mass (amu/Q) in the range that includes helium. Masses heavier than 6 amu/Q were not being sampled at that time because of operation in the high-time-resolution mode for the CCGE.

The reduction in the magnetosheath ion fluxes may be due to the LM exhaust gas stopping the ions by charge exchange and collisional deenergization before they reach the SIDE. Another possibility is that the LM exhaust gas distorts the magnetosheath magnetic field so that the ions are deflected from the SIDE look direction. Preliminary range-energy calculations indicate that the mass of the LM exhaust gas was probably sufficient to stop the ions. The recovery time may thus indicate the time required for the local dispersal of the LM exhaust gas.

Simultaneously with the preceding events, the Apollo 14 SIDE also measured the fluxes of magnetosheath ions. No unusual changes were detected in the time period that included the LM

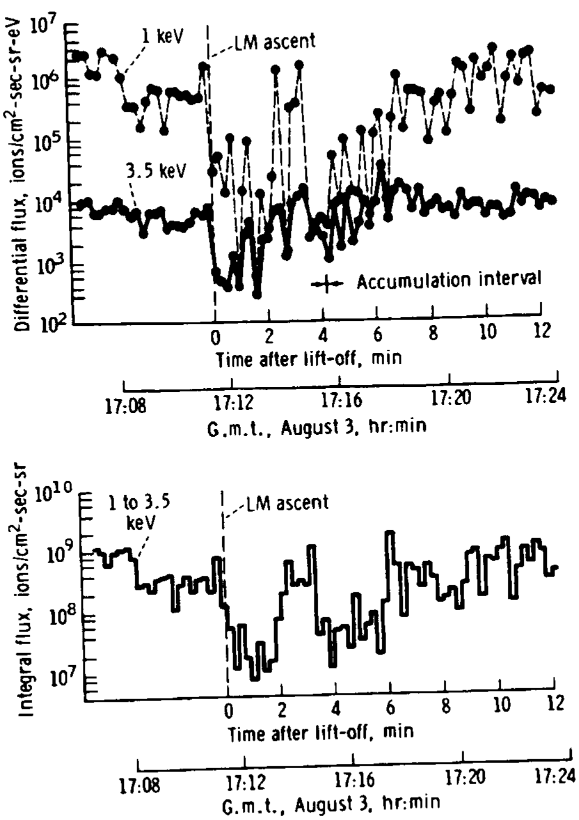

FIGURE 12-5.–Apollo 15 ALSEP differential and integral fluxes of magnetosheath ions during the ascent of the Apollo 15 LM. Greenwich mean time and minutes after ascent are shown. The integral flux is obtained from the 11 energy channels, which cover the range 1 to 3.5 keV. The accumulation interval of the differential flux data points is 1.13 sec (or 1/11 of the integral flux-accumulation interval). The separation between successive differential data points is 13.3 sec.

ascent. This fact confirms the theory that the events at the Apollo 15 site shown in figure 12-5 are local effects produced by the LM exhaust gas and do not result from large-scale temporal changes in the magnetosheath ions. A detailed analysis of this event may provide further insight into the behavior of gas clouds on the lunar surface.

Impact Events

On August 26, 1971, an ion event apparently caused by meteoroid impact was detected by both the Apollo 15 and 14 SIDE instruments. A time delay between the observations indicates an apparent movement of the source. At 22:14 G.m.t., the total ion detector of the Apollo 15 SIDE began detecting ions with energies between 3000 and 3500 eV. The event lasted approximately 130 sec, and no significant counts were recorded before or after this period.

At 22:39 G.m.t., after a delay of nearly 26 min, the total ion detector at the Apollo 14 site began to detect high-energy ions. During a period of 560 sec, ions with energies between 2500 and 3500 eV were detected. The ion observations at both sites are given in figure 12-6. The similar high energies recorded, which are very unusual for this time of the lunar cycle, indicate that the events observed at the two different sites probably had a common source. The SIDE at the Apollo 12 site, 180 km to the west of the one at the Apollo 14 site, did not observe any significant counts during the entire period in question, possibly because of the different look direction. The Apollo 12 instrument is looking 15° to the west of the local vertical, whereas those of Apollo 14 and 15 are looking 15° to the east. This orientation would imply that the ion fluxes observed were directional and generally pointed to the west. It is also possible that the source of the ions moved through a region from which the ions could not reach the Apollo 12 SIDE detector.

The Apollo 14 and 15 passive seismic experiments recorded a seismic event of impact character at approximately 21:00 G.m.t.[2] The impact point was estimated to be within 1000 km of both the Apollo 14 and 15 ALSEP sites.

Despite the long delay of approximately 74 min between the onset of the seismic signal and that of the energetic ions, the two events may be related. At the Apollo 15 site, the time was approximately 31 hr before sunrise; the sunlight terminator was 440 km east of the instrument, and the distance to the assumed average solar wind overhead was 14 km. The seismic data place the impact point on the night hemisphere of the Moon. Therefore, for the impact-generated gas atoms to be ionized, the cloud had to expand into either the solar wind or the sunlight. A more precise determination of the impact point on the basis of seismic data will allow an estimate of the time required for the gas cloud to arrive at the ionization region. Once ionized, the particles would have to travel thousands of kilometers along the interplanetary electric field to attain the observed energies, assuming that the **V × B** solar-wind-induced

[2] G. V. Latham, private communication, Sept. 13, 1971.

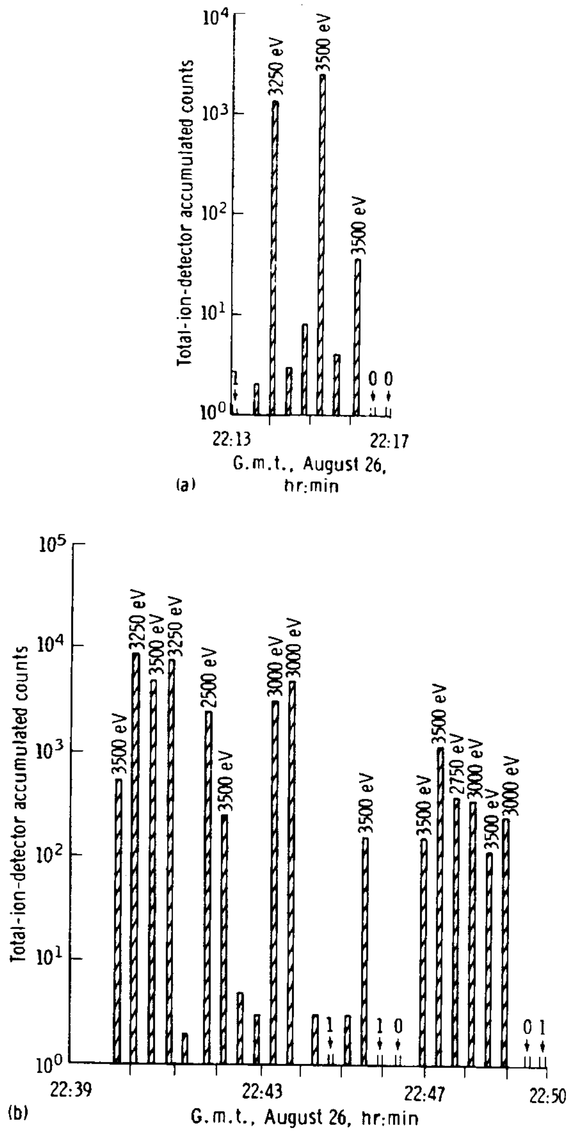

FIGURE 12-6.–Observation of the high-energy-ion event on August 26 by the Apollo 15 and 14 SIDE instruments. All total-ion-detector counts accumulated in the five adjoining 2500- to 3500-eV channels of each 20-channel spectrum are given. Practically all significant counts fell within these five channels. The energy of the peak channel is indicated. This event occurred approximately 75 min after the observations of a seismic event of impact character. The 26-min delay between arrivals at the Apollo 15 and 14 instruments should be noted. (a) Apollo 15 SIDE. (b) Apollo 14 SIDE.

electric field is the acceleration mechanism. Detailed calculations will show if all these factors can account for a delay of more than an hour.

A similar event, with a delay time of 36 min, was detected March 19 by the Apollo 14 and 12 SIDE instruments (ref. 12-3). Both of these events are now thought to be related to the impact events. If the ion events are related to the seismic events, then an apparent mean travel velocity for the gas cloud can be determined for the August event. Assuming a seismic-wave velocity of approximately 100 m/sec (ref. 12-4) and a distance between the seismometer and the impact point of approximately 1000 km, the impact must have preceded the recording of the seismic events by approximately 160 min. This estimated impact time implies that the travel velocity of the cloud was approximately 0.08 km/sec. Another apparent travel velocity could be calculated from the site separation and the time delay between ion arrivals at the two sites. This velocity, approximately 0.7 km/sec, would be valid only if the ion source moved directly from the Apollo 15 site to the Apollo 14 site. Such motion is ruled out here by the seismic information on the impact location.

Lunar Module Impact

At 03:03:36 G.m.t. on August 3, the LM ascent stage impacted the Moon 93 km west-northwest of the Apollo 15 ALSEP. Later, the SIDE detected an ion event involving ions with energies of 10 to 20 eV and dominant masses in the range of 16 to 20 amu/Q. These ions apparently originated from ionization of the gas cloud generated by the impact. At impact time, the total ion detector was recording typical magnetosheath ion spectra with energies peaked at approximately 1 keV, and the mass analyzer detector gave a constant zero reading. The mass-analyzer-detector data at 16.2 eV after the impact are included in figure 12-7(a), which shows the accumulated counts in the mass channels (13 to 16) in which the peak readings occurred. No significant counts were recorded at 48.6 eV, the only other energy channel observed during this event. The total-ion-detector counts accumulated in the 10- and 20-eV channels (those nearest the 16.2-eV energy range of the ions detected by the mass analyzer detector) are given in figure 12-7(b). The accumulated counts of the 500- to 1500-eV channels of the total ion detector are shown in figure 12-7(c). These counts are representative of the magnetosheath ion intensity. The observation of impact-related ions may be divided into two separate time segments. Part 1 covers the first 7 min after impact, and part 2 covers the time between 23 and 28 min.

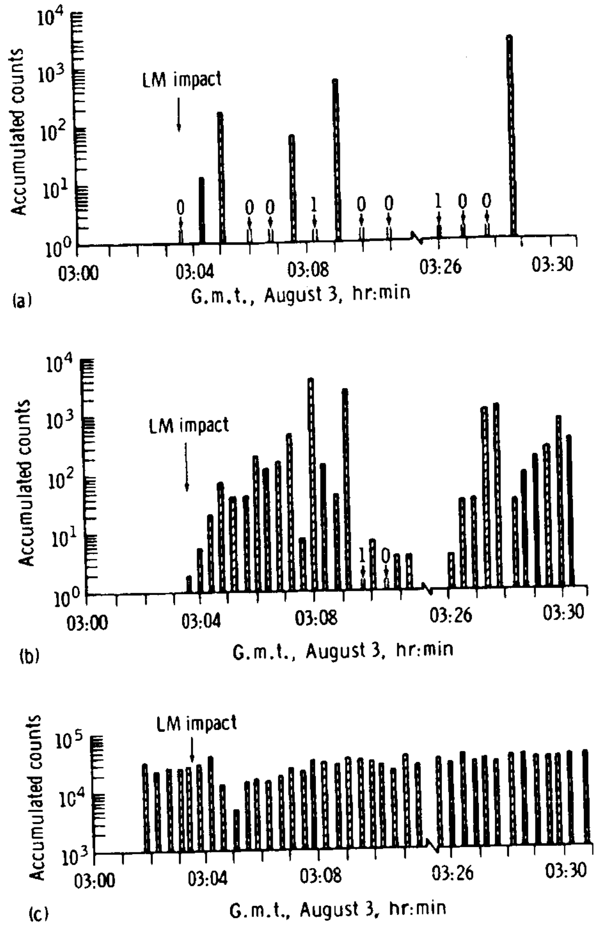

FIGURE 12-7.–Observation of the Apollo 15 LM impact. (a) Mass analyzer detector: sum of the counts accumulated in the mass channels 13 to 16 (masses 12 to 38) at the 16.2-eV energy step. (b) Total ion detector, 10 to 20 eV: counts accumulated in the adjoining 10- and 20-eV energy channels that are nearest the 16.2-eV range of ions detected by the mass analyzer detector. Significant counts were recorded only during the two time periods shown in the figure. Only background counts were recorded at other times, including the interval from 03:12 to 03:25 G.m.t. (c) Total ion detector, 500 to 1500 eV: counts accumulated over an energy range between 500 and 1500 eV. These counts represent typical magnetosheath ions.

The first response of the SIDE was detected (by the mass analyzer detector) approximately 1 min after impact, indicating fairly monoenergetic ions in the mass range between 16 and 20 amu/Q (fig. 12-8). These ions were probably preceded by ions of roughly 1-keV energy that caused a slightly increased counting rate of magnetosheath ions at 03:04:20 G.m.t. (fig. 12-7). However, this increase may have

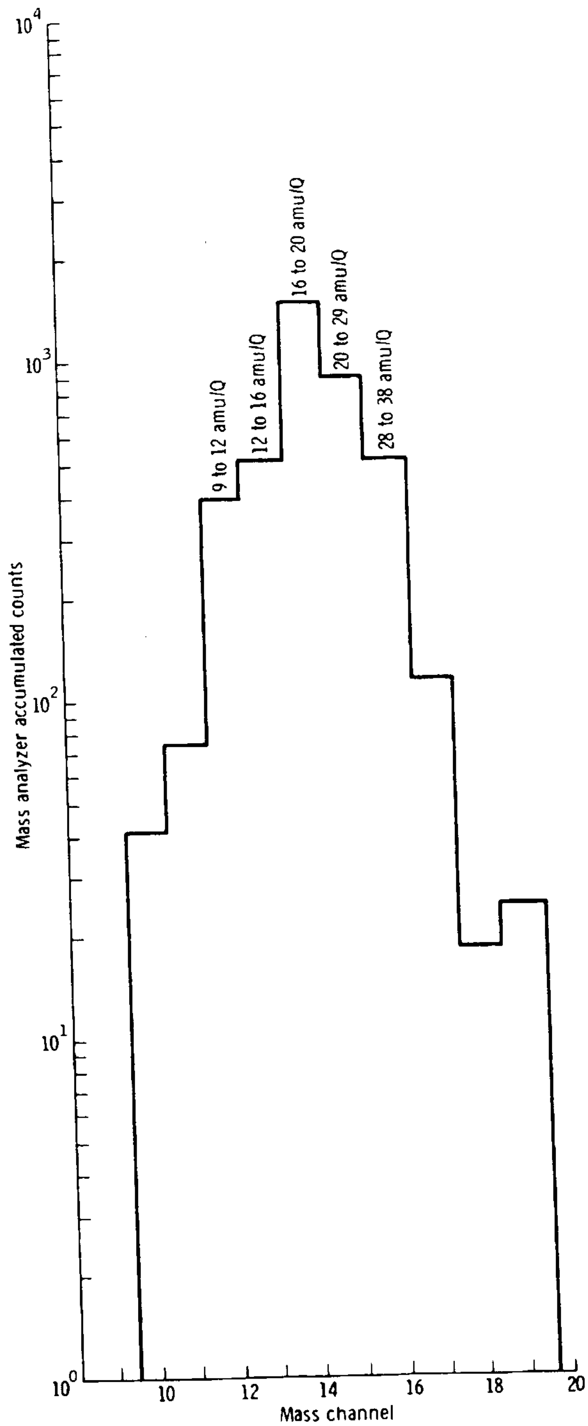

FIGURE 12-8.–Cumulative mass spectrum observed by the mass analyzer detector, including all counts shown in figure 12-7. The mass ranges (amu/Q) of each channel are indicated. The spectrum was taken at the 16.2-eV energy step.

resulted from the normal fluctuations of the magnetosheath ion intensities. For the following 5 min, both the mass analyzer detector and the total ion detector indicated the presence of ions with energies between 10 and 20 eV and masses in the range 16 to 20 amu/Q. At the same time, the counting rates resulting from magnetosheath ions in the energy range between 500 and 1500 eV showed a significant decrease (by a factor of 8), which is believed to be caused by charge exchange or scattering in a neutral gas cloud (or both). The LM impact presumably generated a gas cloud that moved outward from the impact site. The low-energy ions seen by the SIDE are thought to result from ionization of this cloud.

The apparent travel velocity of the cloud, calculated from the distance between the Apollo 15 ALSEP and the impact point and from the time delay between impact and the first observation of ions, is 1.6 km/sec. If the neutral gas cloud arrived at the ALSEP site at the same time as the first ions, as implied by the magnetosheath ion data, the expansion velocity would correspond to a gas temperature of approximately 2000 K. The mass spectrum and the energy of the ions of part 2 of the event are in very good agreement with those of part 1. This agreement leads to the conclusion that both parts form one single event despite the separation in time. However, in part 2, no evidence exists for an associated neutral gas cloud. During part 2, the maximum flux for the total event was observed as 3×10^7 ions/cm^2-sec-sr-eV. If it is assumed that the gas generated by the impact was expanding in a hemispherical shell, the fluxes at the Apollo 14 and 12 sites would be near the limit of detection for the instrument. This may explain the absence of any impact-related ion observations by the Apollo 12 and 14 SIDE instruments.

Magnetosheath of the Earth

The Apollo 12, 14, and 15 SIDE instruments are deployed so that their respective look directions, depicted in figure 12-4 for the case of zero libration, are approximately 38° west, 2° west, and 19° east of the Earth. Thus, a three-point observation can be made of the angular distribution of ions in the magnetosheath. The result of such an observation reveals a highly directional flow of energetic ions moving downstream parallel to the magnetosheath. Simultaneous observations at the three sites were obtained in real-time operations on August 3, shortly before the LM impact. Sample energy spectra recorded by the total ion detectors are shown in figure 12-9. The Apollo 15 instrument recorded a relatively steady flux of magnetosheath ions, with an energy spectrum peak at 750 to 1000 eV. The Apollo 14 detector measured a less intense flux of ions with similar energies. The Apollo 12 SIDE recorded only a small counting rate, approximately background level for that instrument at that temperature.

At the time of these observations, the Moon was just inside the bow-shock front near the position marked "Apollo 12 ALSEP sunrise" in figure 12-4. The magnetosheath fluxes had been detected steadily for at least 15 hr by the Apollo 14 SIDE, and multiple crossings into and out of the magnetosheath were detected earlier. It can be seen from figure 12-4 that the Apollo 15 instrument was detecting ions moving downstream nearly parallel to the bow-shock

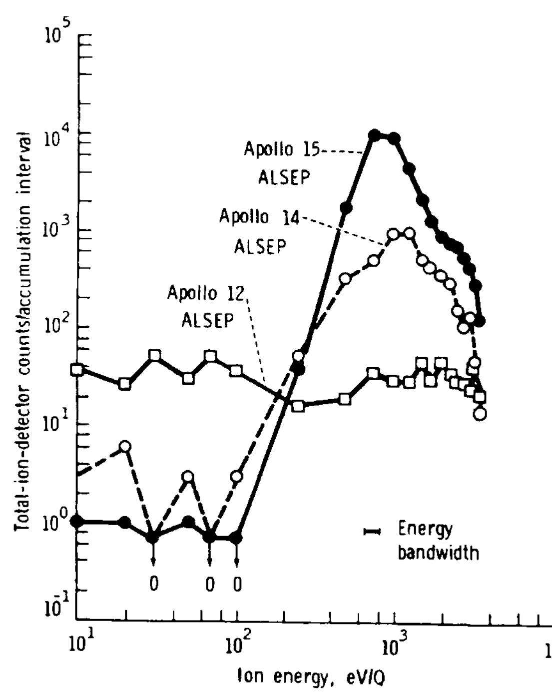

FIGURE 12-9.–Ion-energy spectra detected by the three SIDE instruments in the magnetosheath region on August 3. The Apollo 12 ALSEP spectrum began at 03:02:34 G.m.t., the Apollo 14 ALSEP spectrum at 03:02:33 G.m.t., and the Apollo 15 ALSEP spectrum at 03:02:25 G.m.t. The three instruments look in widely separated directions, as shown in figure 12-4. The accumulation interval for one data point is 1.13 sec of the 1.2 sec/frame.

front, while the Apollo 14 and 12 instruments were detecting ions moving at angles of approximately 21° and 57°, respectively, to the shock front. Thus, the intensity of the ions streaming down the magnetosheath was reduced by a factor of 10 at 21° angle and was further reduced by an additional factor of approximately 40 at 57°. The low counting rates of the Apollo 12 SIDE at this time are typical of the data recorded by that instrument at this place in the magnetosheath over the previous 21 months, although, occasionally, the streaming ions have been observed. On the other side of the magnetospheric tail, the situation is reversed. There, the Apollo 12 and 14 instruments look upstream, while the Apollo 15 detector looks at a large angle to the shock front.

Miscellaneous Observations

The Apollo 15 SIVB impact, which occurred before the deployment of the Apollo 15 ALSEP, was monitored by the SIDE instruments of Apollo 12 and 14. As in previous such events (refs. 12-3 and 12-5), the positive ions produced from the resulting gas cloud were observed. The event was relatively well defined at the Apollo 14 ALSEP site, but the Apollo 12 SIDE recorded only a very brief, low-intensity event. This difference probably results from the fact that the Apollo 12 instrument was looking generally away from the impact, whereas the Apollo 14 instrument was looking toward it. In addition, the Apollo 12 site was farther into the dark side of the Moon at the time and thus was farther removed from areas where ions could be produced by solar ionization of the neutral gas cloud.

Three LM-cabin-depressurization events were observed after deployment of the Apollo 15 ALSEP. The SIDE/CCGE was operated at these times primarily to enable the CCGE to detect the neutral-gas-pressure effects of the cabin venting. Thus, the mode of operation was one that optimized CCGE temporal resolution and that cycled through only the first 11 SIDE mass channels, covering the range up to 6 amu/Q. Although counts were recorded by the mass analyzer detector during these events, no spectra are presented here because of the small mass range covered and the rapid temporal variations of intensity observed during these periods.

Observations during the August 6 total eclipse of the Sun were made with the Apollo 12 and 14 SIDE instruments, but no unusual events attributable to the eclipse were recorded. The Apollo 15 instrument was operating with high voltages commanded off, as planned, while outgassing of the instrument took place.

The Apollo 15 SIDE high voltages were commanded on near sunset of the first lunar day and operated throughout the night and into the next day, as discussed in the paragraph on performance of the instrument. At various times throughout the night, short-duration ion events were observed, similar to those recorded by the two earlier SIDE instruments (refs. 12-1, 12-6, and 12-7). The present three-site network of observing instruments makes it possible to distinguish between events of a local nature and those of global scale. Apparent motions of ion events can also be determined in many cases. Complete analysis must await the receipt of flight data tapes from all three ALSEP units. The available data, mostly from the Apollo 14 and 15 instruments, show some events that are observed at only one site (either 14 or 15) and other events that are observed at both sites. The addition of the simultaneous Apollo 12 data will allow more comprehensive determinations of the character of these events.

CONCLUSIONS

The Apollo 15 SIDE is performing excellently and is returning very useful scientific data. These data are especially valuable in conjunction with the simultaneous data from the Apollo 12 and 14 SIDE instruments, which are still operating. Preliminary analysis of the data yields the following significant observations.

(1) Multiple-site observations of ion events apparently related to a meteoroid impact have led to the determination of apparent motions of the ion source. The source is presumed to be neutral gas that moves outward from the impact and becomes ionized. The apparent travel velocity of the gas cloud is calculated as approximately 0.08 km/sec.

(2) A complicated ion event related to the Apollo 15 LM impact was detected by the Apollo 15 SIDE. A small flux of 10- to 20-eV ions was observed within a minute after the impact. At 26 min after the impact, an intense flux of 10- to 20-eV ions was recorded. These ions exhibited a broad mass spectrum, with a peak in the range 16 to 20 amu/Q. Both the meteoroid event and the LM-impact event produced a second ion-flux increase observed at a time several minutes after the initial increase.

(3) At LM ascent, a strong decrease occurred in the magnetosheath ion fluxes being detected at the time. This decrease, which lasted approximately 8 min, could be attributable to energy loss in the relatively dense exhaust gas, to losses by charge exchange, or to temporary deviations of the magnetosheath ion-flow direction caused by the exhaust gas.

(4) The 500- to 1000-eV ions streaming down the magnetosheath have been observed simultaneously by all three SIDE instruments, located at different sites and looking in different directions. The ion flux is strongly peaked in the downstream direction, decreases by a factor of 10 within a 21° change in direction, and further decreases by an additional factor of approximately 40 within the next 36°.

(5) As with the Apollo 12 and 14 SIDE instruments, short-duration energetic ion events have been observed during the lunar night by the Apollo 15 SIDE. Analysis of these events from simultaneous observations at three sites will lead to a more comprehensive determination of the characteristics and causes of these events.

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