Apollo 17 Lunar Ejecta and Meteorites Experiment (LEAM)

Film ID numbering convention used in the LEAM data

The LEAM data set uses an identifier denoting which of the 16 sectors of the film array registered a hit. The identifier was used on the front and rear arrays of the east-facing and up-facing sensors. Since 4 bits are allocated to each of these IDs, the number recorded will be from 0 to 15. There is no explicit documentation that we have found describing the numbering convention on the arrays, i.e., which number corresponds to which position on the array. This document describes how we tried to determine the numbering convention.

The only diagram we could find in any of the documentation that showed the numbering convention on the sensors was in Otto Berg's first Cosmic Dust Detector (CDD) notebook [1] on page 111 (figure 1). This diagram is for the dust detector instrument on Pioneer 8 and 9, not the LEAM, but the array component is said to be identical to the array component of the LEAM instrument [4][5]. We take this further to assume the numbering convention used on Pioneer is consistent with the numbering convention used on LEAM.

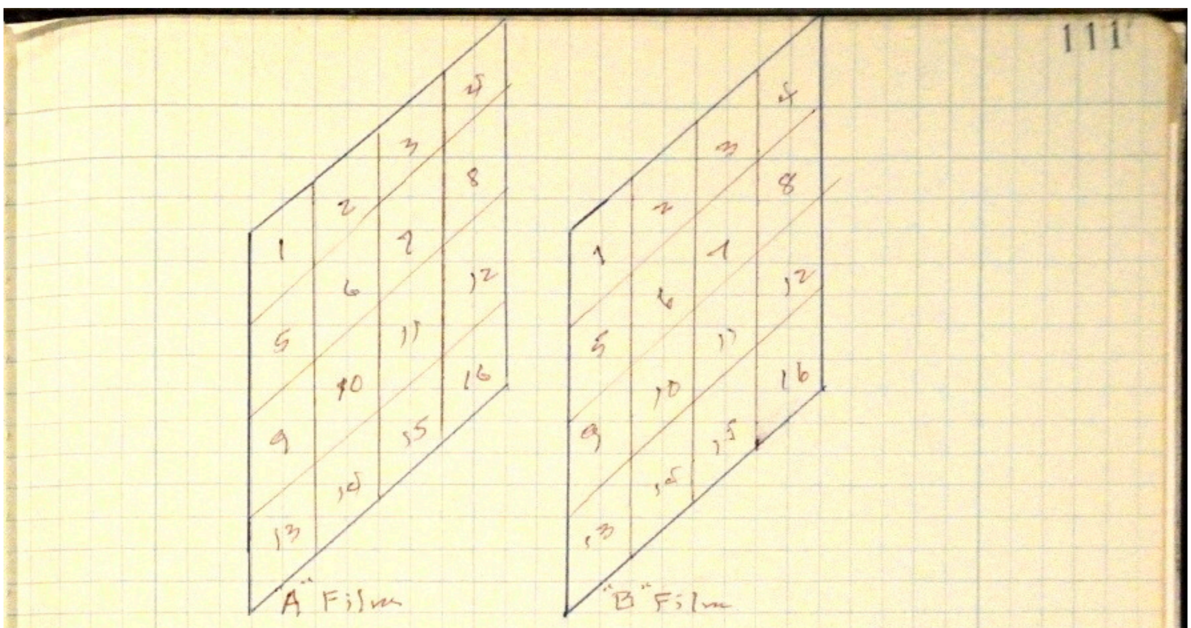


Figure 1 – Pioneer array numbering system, Berg CDD Notebook #1, p. 111 [1]

With these caveats in mind, the drawing at the top of page 111 in figure 1 shows numbers 1 through 16 on the A-film (front array) and B-film (rear array). The sensing parts of each array were four film strips and four grid strips (see appendix). The four film strips and four grid strips run perpendicular to each other, so each of the 16 sections of the array is a unique combination of 1 film strip and 1 grid strip. Figure 2 shows a drawing of the array on page 110 indicating the orientation and position of films 1 through 4 running vertically and grids 1 through 4 running horizontally. This left hand image on figure 2 is viewed from the front (outside) of the Pioneer array, as indicated by the orientation of the LEAM films and grids from Berg's LEAM notebook [2] on page 107 (figure 4) under the assumption the arrays are built the same way. Figure 3 from page 114 shows the particle path coming from the front, passing through the A-film array and then through the B-film array. This establishes the orientation of the Pioneer arrays with respect to the films, grids, and numbers, i.e. figure 1 is looking at the backs of the arrays.

Using this information, viewed from the front (outside the detector) the Pioneer detector will be as shown in figure 5.

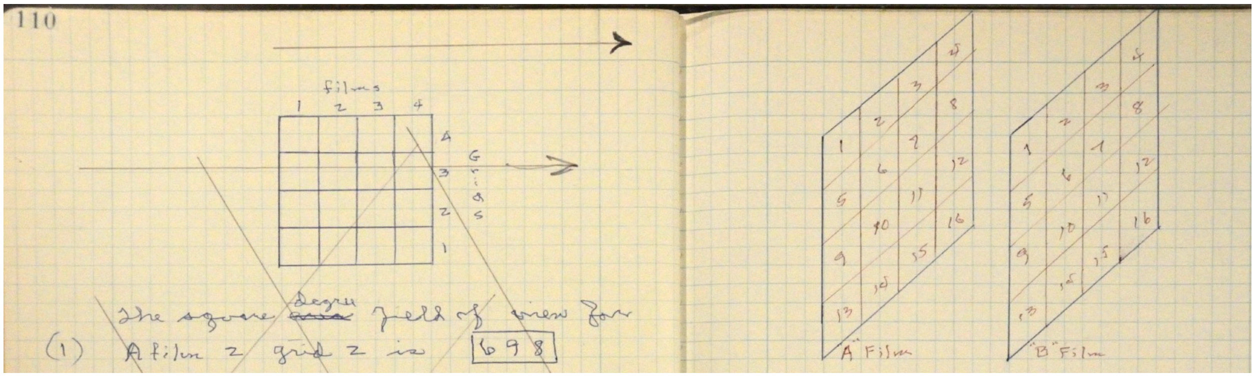


Figure 2 – Diagram showing film and grid orientations from Berg CDD Notebook #1, pp. 110-111 [1]

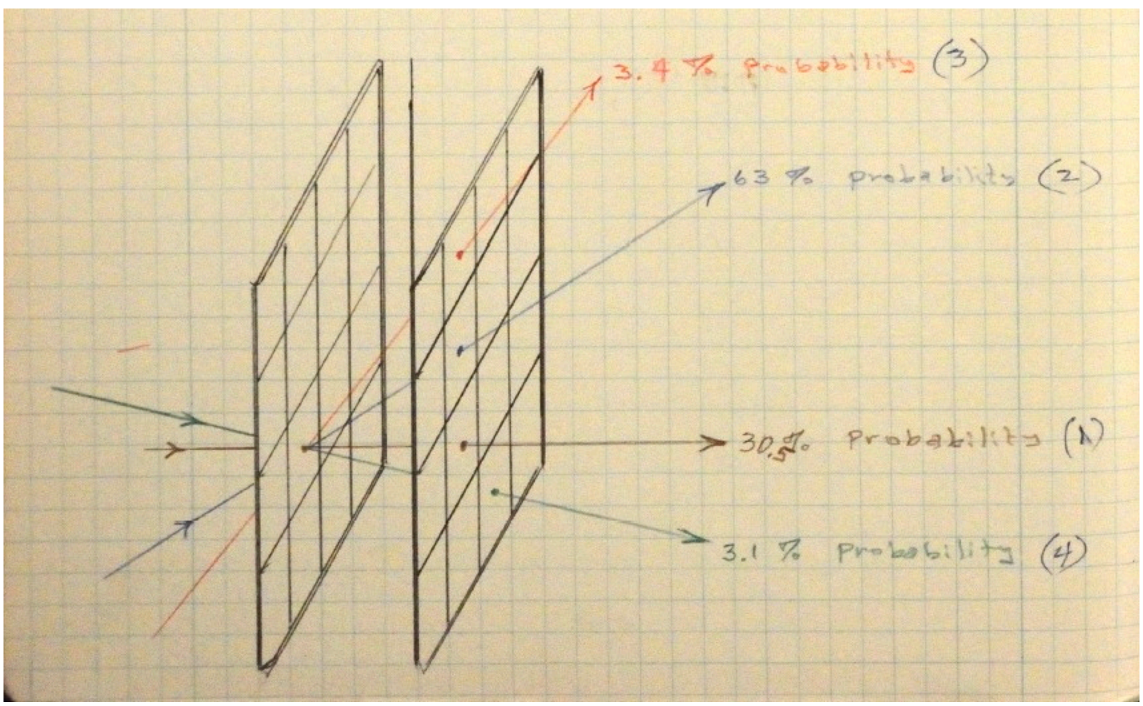


Figure 3 – Pioneer detector particle path from Berg CDD Notebook #1, p. 114 [1]

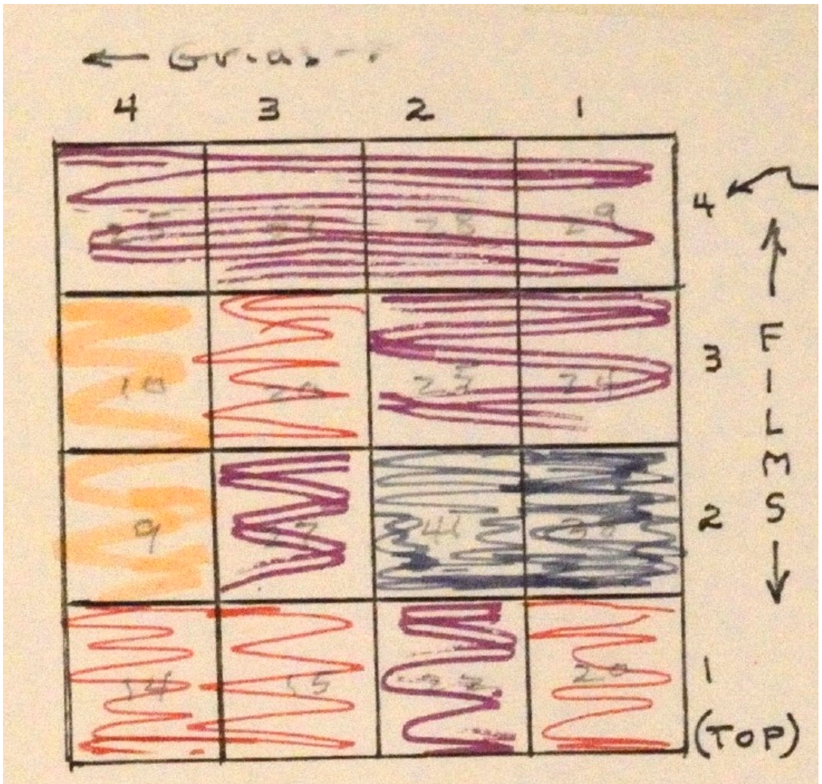


Figure 4 – LEAM grid example showing orientation of films and grids from Berg LEAM notebook, p. 107 [2]

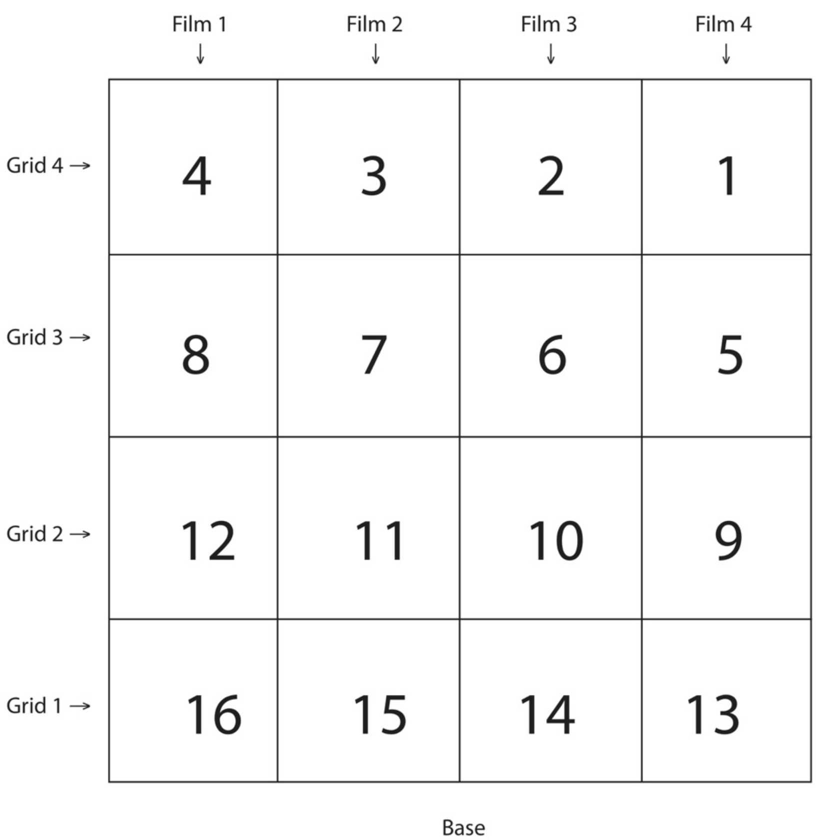


Figure 5 – Grid ID convention for Pioneer 8 and Pioneer 9 Cosmic Dust Detector, as deduced by this analysis.

For the LEAM detectors (see appendix for more details), we have notes from Berg's LEAM notebook [2] on page 126 (figure 6) that give the orientation and location of the films on the east and up sensors. The films run horizontally on the east sensor with film 1 at the top. Therefore the grids are running vertically. For the Up sensor, the films run basically north-south (the detector was oriented 25 degrees from north-south) with film number 1 on the west side.

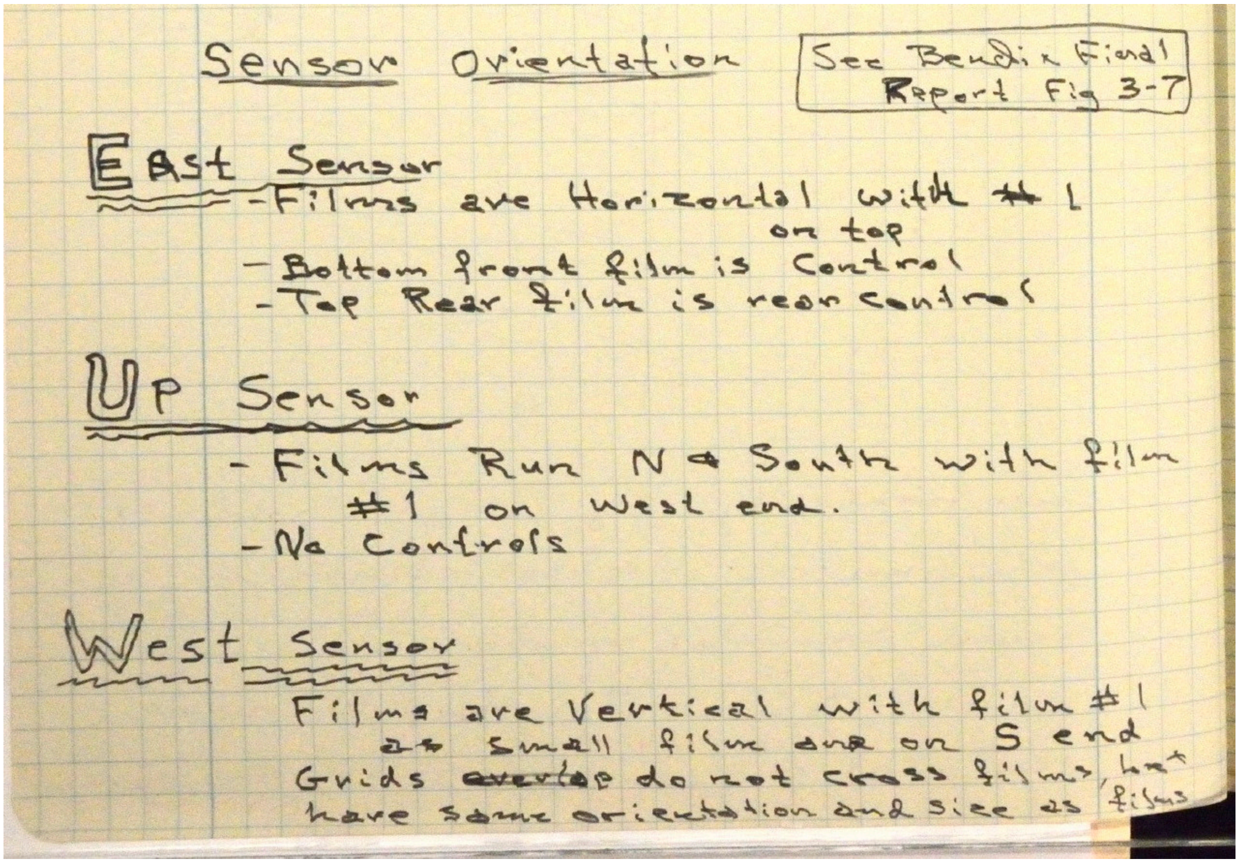


Figure 6 – Orientation of sensors on LEAM from Berg LEAM notebook, p. 126 [2]

This is clarified in figure 7, from reference [6]. This is the figure referred to in Berg's written note in the upper right corner of figure 6 ("See Bendix Final Report Fig 3-7") and shows the orientations of the sensors, films, and grids as set out on the lunar surface. As can be seen from the description in figure 6 and the diagram in the appendix showing the configuration of the films and grids, figure 7 shows the grids for the east and up sensors (denoted AC1 – AC4) and the films for the east and up sensors (denoted AF1 – AF4) in their orientation as deployed on the Moon.

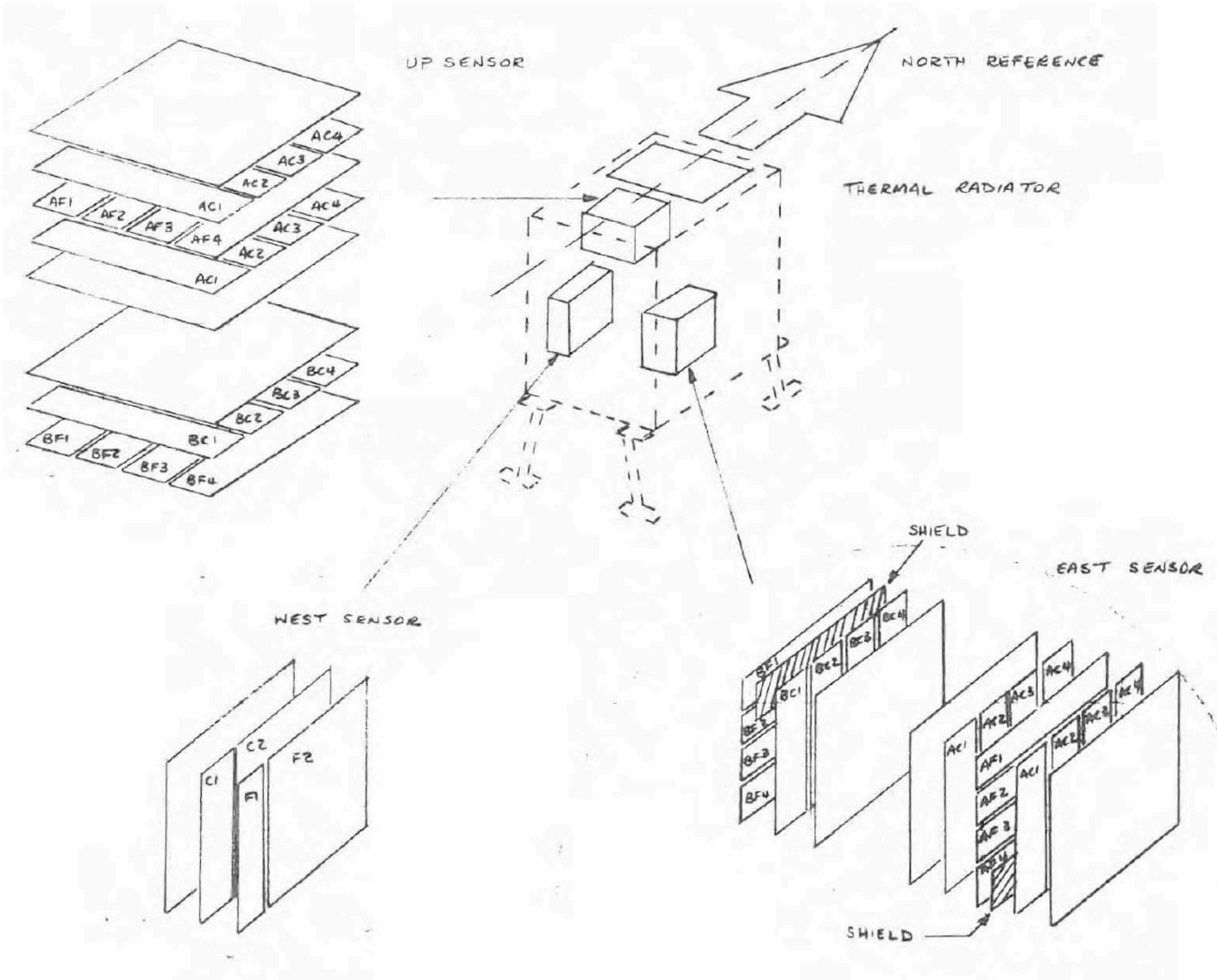


Figure 7 – Orientation of sensors, films, and grids as placed on lunar surface, from figure 3-7, p. 3-30 in the LEAM Final Report [6]

This is also verified in other pages in Berg's LEAM notebook [2], for example figure 8 from page 107. This shows the east sensor at the top and the up sensor below it. The film numbers are listed along the sides with the films running horizontally in the figure, and the grid numbers are listed along the top with the grids running vertically. Note that the east sensor diagram has the actual top of the east center shown at the bottom – film 1 was at the top of the array. Later diagrams in this document will show the east array oriented with the top up. The up array is oriented with respect to the compass points shown on the right in figure 8. It is also confirmed that the diagrams are looking at the arrays from the outside, not the inside, by the fact that the west array, at the bottom of figure 8, has film 1 running along the south side, in agreement with the description in figure 6. Figures 6 and 8 can only be consistent with the compass directions shown if the arrays are viewed from the outside. If we assume the numbers from the Pioneer sensors (figure 5) with respect to the films and grids are the same, we come up with figures 9 and 10 showing the ID configuration for the LEAM sensors, with the equivalent 1-16 numbering convention as in figure 1.

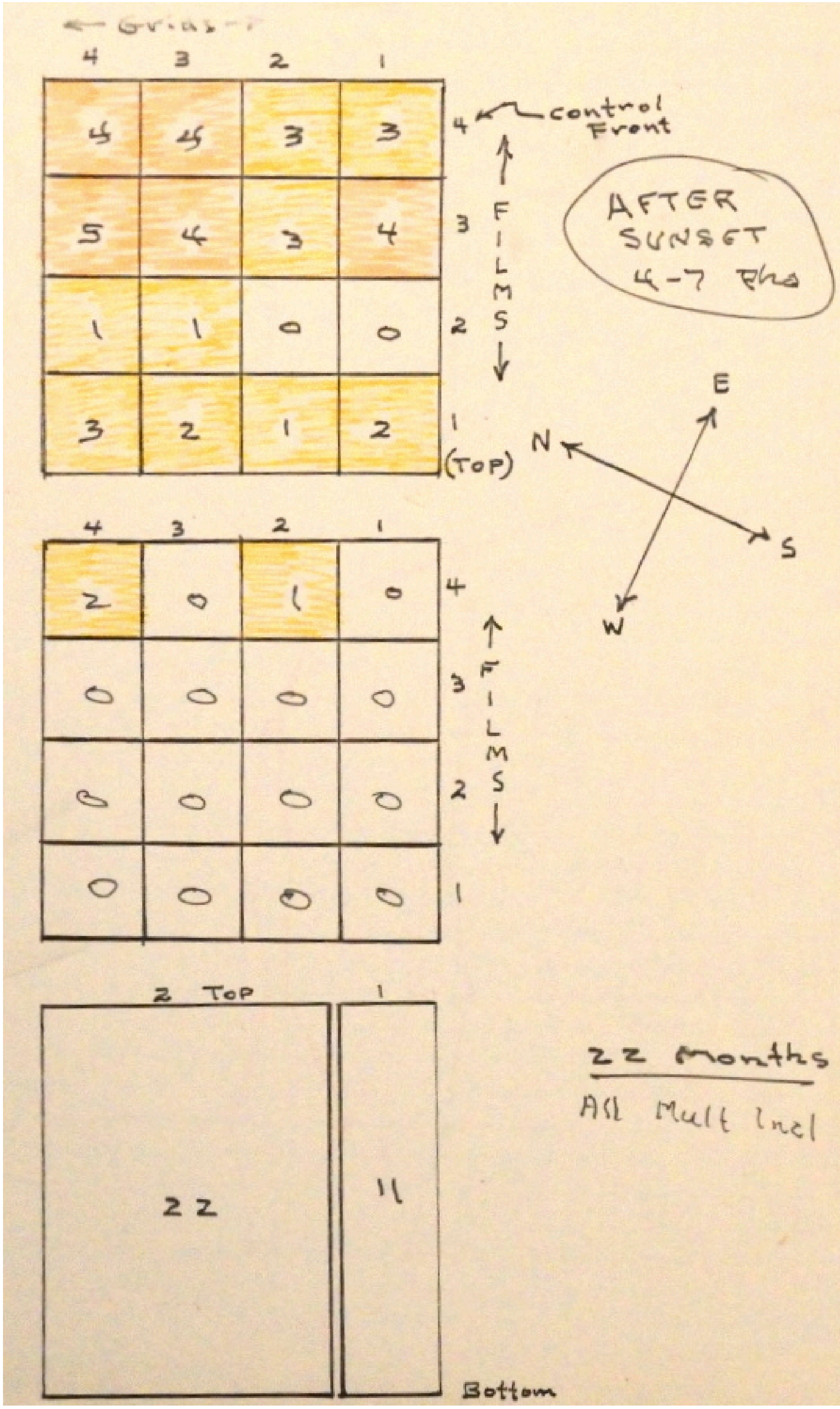


Figure 8 – Diagrams of hits registered on LEAM east, up, and west sensors showing the orientation of the films and grids from Berg LEAM notebook, p. 107 [2]

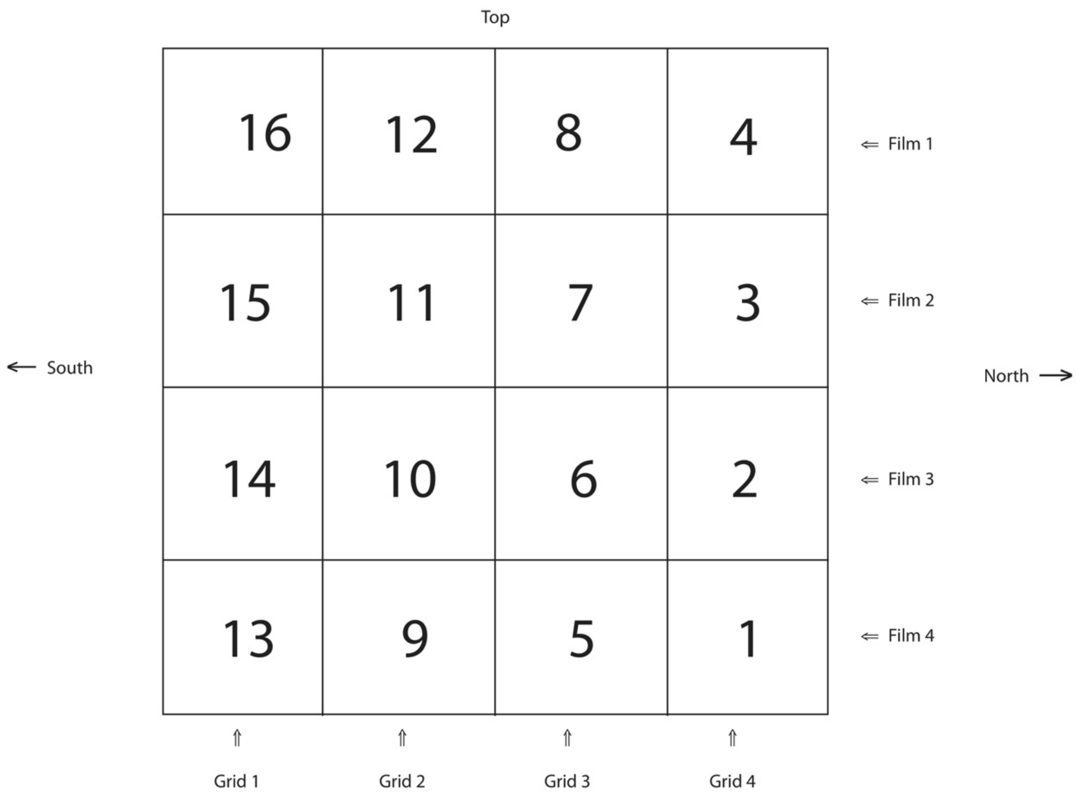


Figure 9 – LEAM east sensor looking at the front (from the outside) with the films, grids and IDs using the Pioneer convention, as deduced by this analysis.

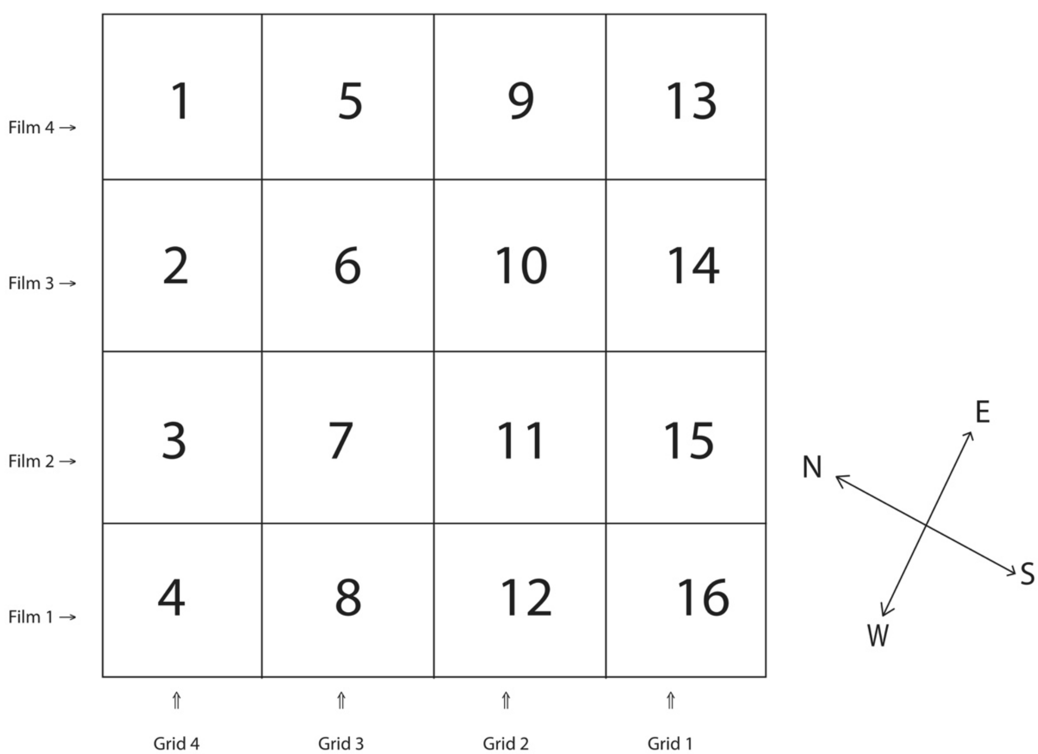


Figure 10 – LEAM up sensor looking from above, using the Pioneer convention, as deduced by this analysis.

As noted at the beginning of this document, the LEAM data measurement IDs range from 0 to 15, not 1 to 16. We assume this translates as the above ID grid minus 1, which gives figures 11 and 12 as our best estimate of the ID convention used on the LEAM east and up arrays, again, as looking at the arrays from outside the instrument.

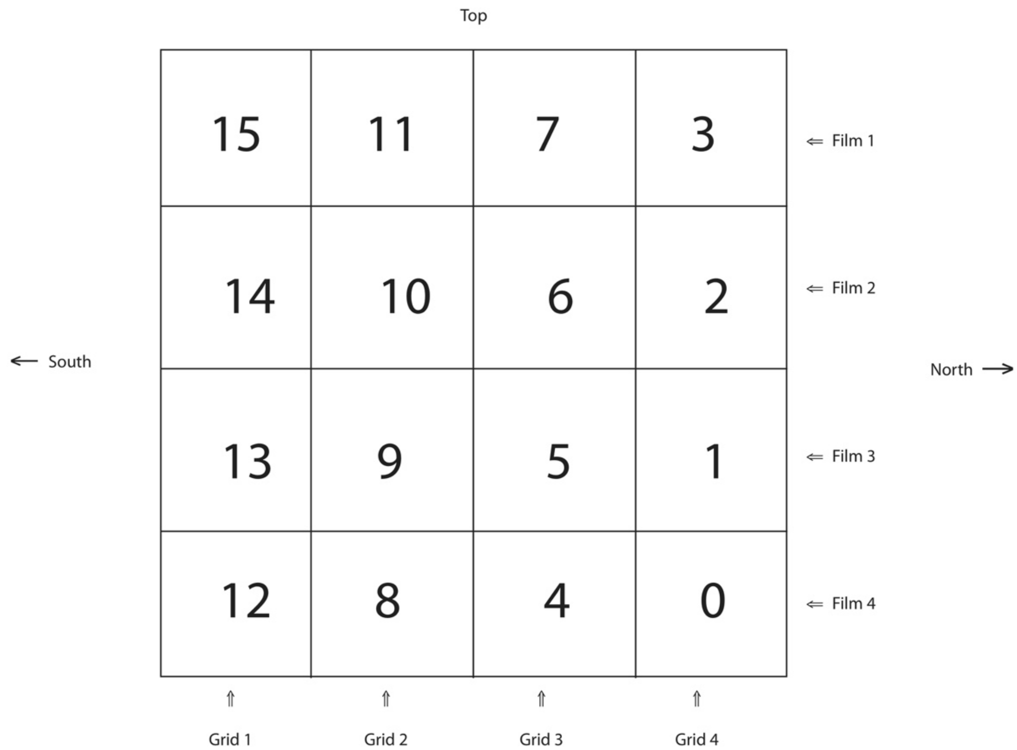


Figure 11 - LEAM east sensor looking from the outside with IDs from 0 – 15, as deduced by this analysis.

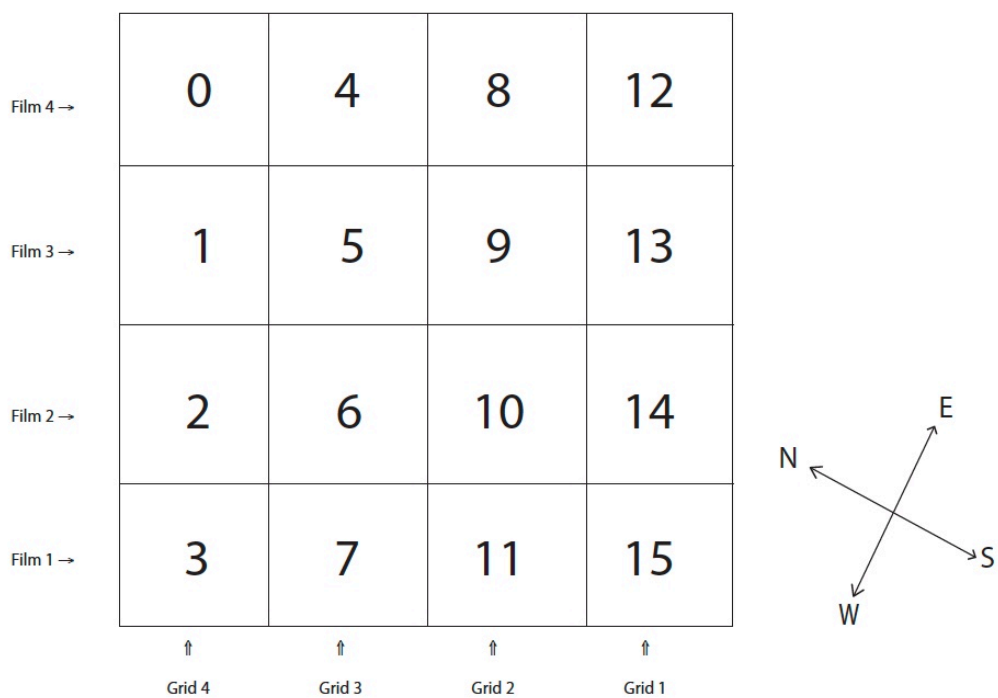


Figure 12 – LEAM up sensor looking from above, with IDs from 0 – 15, as deduced by this analysis.

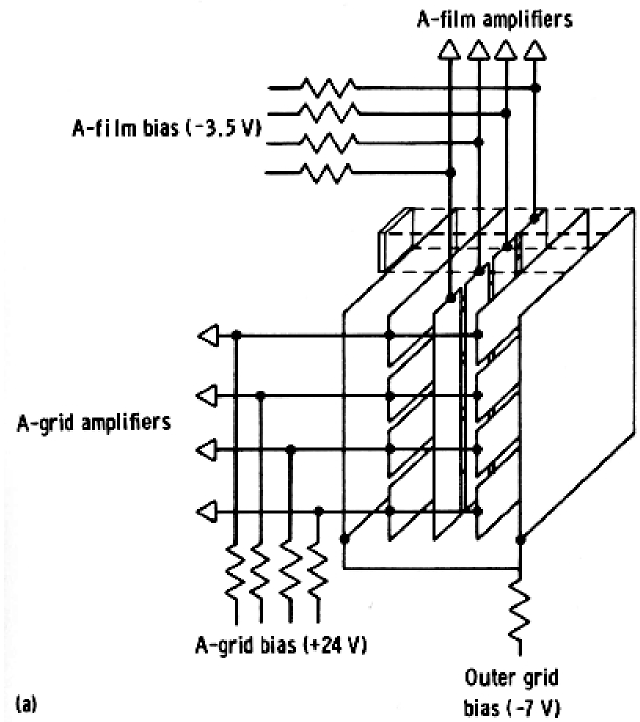
Our analysis depends critically on the following three assumptions:

1) The array identifier convention on LEAM is the same as the convention used on Pioneer 8 and 9. – Since the experiments are described as being essentially similar and had the same P.I., there is little reason to think a different convention would have been used.
2) The array orientations are the same in figures 1 and 3, i.e. both are looking at the back of the array. – figure 3 is looking at the back, it seems clear that figure 1 is the same view.
3) The numbering convention 1-16 can be simply converted to 0-15 by subtracting 1 from each number. – No other transformation scheme seems to make sense.

Appendix – Mechanical description of the LEAM sensor arrays

LEAM had three sensors, the “up”, “east” and “west” sensor arrays. The up sensor was mounted on top of the LEAM box, looking directly upwards. The east sensor was mounted on one vertical face of the box, facing 25 degrees north of east. The west sensor was on the opposite side, facing 25 degrees south of west, but had a different configuration and is not discussed here. The up and east sensors had virtually identical configurations, each comprising 2 planar sensor arrays, a front and a rear array.

The front planar sensor array (see figure below, from [3]) had five basic components, all were approximately 10 cm square plates stacked in a parallel fashion. The outermost component was a thin beryllium copper wire mesh, called the suppressor grid, which was kept at a potential of -7 volts. The mesh was supported by a thin lexan structure which formed an array with 4 x 4 square (2.5-cm on a side) openings. Mounted on the other side of the support structure was the collector grid, made of four parallel 2.5 x 10 cm thin beryllium copper wire grid strips oriented "horizontally" (directions given in reference to the figure below) covering the 10 x 10 cm



detector area (the A-grid). The collector grid was isolated from the suppressor grid and kept at a bias of +24 V. Each strip was connected to a separate amplifier.

Behind the collector grid was the film sensor array which comprised four parallel conducting film strips (the A-film) oriented "vertically" in a plane normal to the sensor direction. The film was composed of three layers of parylene with metals deposited on the surfaces of each layer to give a composite sheet of, from front (outward-facing) to back, 300-A (angstrom) thick aluminum, 700-A parylene, 500-A copper, 300-A aluminum, 3000-A parylene, 300-A aluminum, 500-A copper, 500-A parylene, adhesive, and a beryllium copper mesh. Each film strip was held at a potential of -3.5 V and was connected to an amplifier. Behind the film sensor array was another collector grid, identical to the first and connected to it electrically. The four horizontal grid strips and four vertical film strips defined the 16 distinct 2.5 x 2.5 cm square areas on the grid. Directly behind the collector grid was a suppressor grid identical to the front suppressor grid and connected to it electrically. The rear planar array (B) was mounted 5 cm behind the front array and consisted of a suppressor grid, collector grid (B-grid), and film sensor array (B-film) identical to the A array but without the second collector and suppressor grids.

References

[1] Berg, O.E. and D.R. Williams, "Pioneer 8 and 9 Cosmic Dust Detector Calibration Notebook Bundle", NASA Planetary Data System, ID: urn:nasa:pds:pioneer89cdd, 2017. Digital reproduction of two hand-written laboratory notebooks, #1 and #2, of calibration analyses for the Pioneer 8 and 9 Cosmic Dust Detectors (CDD). These results aided Berg's calibration effort for the Apollo 17 Lunar Ejecta And Meteorite Experiment (LEAM) detector which was identical to the Pioneer CDDs.

[2] Berg, O.E., D.R. Williams, M. Gaddy, "Apollo 17 Lunar Ejecta And Meteorites Experiment Calibration Notebook Bundle", NASA Planetary Data System, ID: urn:nasa:pds:a17leamcal, 2017. Digital reproduction of one hand-written laboratory notebook of calibration analysis for the Apollo 17 Lunar Ejecta And Meteorites (LEAM) Experiment detector which was identical to the Pioneer 8 and 9 Cosmic Dust Detectors (CDD).

[3] Apollo 17 Preliminary Science Report, Chapter 16, NASA SP-330, NASA, Washington, D.C., 1973.

[4] Berg, O.E., and F.F. Richardson, "The Pioneer 8 Cosmic Dust Experiment", NASA Technical Note D-5267, NASA, Washington, D.C., 1969.

[5] Wolf, H., "Data Analysis to Separate Particles of Different Speed Regimes and Charges", NASA-CR-159916, Analytical Mechanics Associates, Inc., Seabroook, MD, 1977.

[6] Perkins, D.H., Final Report - Analysis of LEAM experiment response to charged particles, NASA-CR-147872, NASA contract no. NAS9-14751, Bendix Aerospace Systems Division, BSR 4234, 1976.