

MOSAICKING DESCRIPTION

1. General Discussion

During the Viking Mission, the Lander Camera System acquired many high-resolution images of the scenes at Chryse Planitia and Utopia Planitia landing sites. Using individual camera events, which occurred on many days throughout the mission, computer mosaics have been created for both sites as viewed by each of the two cameras on the spacecraft.

For Lander 1, two sets of mosaics have been produced; one pair for camera 1 and 2 images acquired early in the morning (7:00-8:00), and one pair for images acquired in the mid-afternoon (14:00-15:30). For Lander 2, three sets of mosaics were compiled: in the morning (7:00-8:00), around noon, and in the early evening (17:00-18:00). Thus a total of ten mosaics have been generated. The general procedures for processing the Viking Lander Camera data are described elsewhere (1). This purpose of this description of the mosaicking process is to provide, to the users of the mosaics, sufficient understanding of the processing so that they will be able to correctly interpret the scenes. The individual camera events that were incorporated into each mosaic are identified in the tables below. The detailed description of each such event, including a reproduction of its image, is given in the Picture Catalog Data Record (2) (EDR). (This publication covers Camera Events 12A001 through 12B198 for VL-1, and 22A001 through 21C070 for VL-2.)

The Lander Camera system (3) incorporates twelve command selectable photo-sensors in each camera (see p. 5-8 ref. (2) for a brief description). Four diodes

(BB1, BE2, BE3, BE4), with an instantaneous field of view of 0.04 degree, are at different distances from the lens, allowing optimization of focus selection (1.9, 2.7, 4.5 and 13.3 m respectively). This results in an overall depth of field from 1.2 m to infinity. Almost all the events used for mosaicking were acquired by those diodes. One diode (survey) with a 0.12 aperture was used for black-and-white panoramas. In a few cases data from this diode was used where no high resolution data was acquired. Otherwise all the mosaic image data was acquired using the 0.04 degree aperture diode.

Each complete mosaicked scene extends 342.5 degrees in azimuth, and from approximately 5 degrees above the horizon to 60 degrees below. A complete mosaic incorporates approximately 15 million picture elements (pixels). In order to manage the processing of such large data bases, each mosaic was compiled from four individual azimuthal quadrants.

The mosaic negatives have been made on an Optronics Photowriter (Model P - 1500) in two forms. In one case, using a 25 micron spot size, the complete four quadrants of a single mosaic is contained on a single 8 X 10 negative. In the second case, three products are made using a 50 micron spot size. They cover quads 1 and 2, 2 and 3, and 3 and 4 respectively on each of three 8 X 10 negatives. The azimuthal coverage for each quadrant is as follows:

Quad	CACCS* Azimuth limits	LACCS** Start Azimuth (Camera 1)	LACCS** Start Azimuth (Camera 2)
1	0°-90°	279.5°	95.5°
2	84°-174°	3.5°	179.5°
3	168°-258°	87.5°	263.5°
4	252°-342°	171.5°	347.5°

*CACCS - Camera aligned camera coordinate system

**LACCS - Lander aligned camera coordinate system

See ref. (2) page 11 and 12 for description of coordinate systems.

Because of the tilt there is no simple correspondence between the azimuth angles for individual camera events, as shown in the EDR, and the azimuth angles provided on the border of the complete mosaics. The azimuth angles shown on the top border of the mosaic products are measured approximately from North.

2. Methodology

a) General Mosaicking Technique

The creation of the Viking Lander high resolution mosaics can be separated into the steps of selection, preparation, mosaicking, and photometric correction. The selection process focuses on the Primary Mission Viking Lander EDR images. In some cases, Extended Mission images are included where primary mission coverage is absent or inadequate. This was often the result of obscurations caused by sample arm activities. From these images, sets of early morning, afternoon, and, for Viking Lander 2, noon frames are selected. A further selection criterion is that the range to the nominal surface plane at each elevation should be matched (as best as possible) with the diode which focuses closest to that range. (For example, the diode designated EE4 has its focus at 13.3 m and a depth of field permitting imaging at infinity. Thus an elevation command of zero degrees in the mosaic should be filled in with an image taken using the EE4 diode.)

After a set of images for each camera and a time of day is selected, the

preparation step is begun. Each image is radiometrically corrected (4,5,6) and differences caused by variations in gain and off-set settings are removed from each image in the set. In addition, a solar lighting correction (based on a model of a Lambertian surface; sine of incidence angle) is performed to remove minor time of day variations in the various images of the set. Next a geometric transformation (5,7) is performed on each image. This transformation is the combination of a camera geometry correction and a de-tilting of the image into a local Mars zenith system. (Both landers are tilted relative to a flat landing plane. Figure 5, page 12, in ref.(2), describes the orientation of both Landers.) The transformed images are now aligned so that the horizon of the nominal surface plane will project into the image as a horizontal straight line.

In the mosaicking step, all images comprising a quadrant are combined into a single image. This process sometimes is preceded by an ad hoc contrast correction of some images (all of them being from the extended mission) for which the previously applied photometric correction alone was inadequate. The mosaicking process proceeds as follows. First, each image is assigned a priority. Then, for each picture element (pixel) the pixel DN value of the highest priority image is examined. If it is non-zero, then that value becomes the DN value of the pixel in the resultant image. Otherwise, the search continues through all pixels in the exact same position in order of decreasing priority until a non-zero DN value is found or until the picture list is exhausted (in which case the resultant DN value for that pixel becomes zero).

After the mosaics have been generated, a general cleanup is performed. Processing artifacts (at image boundaries) and narrow gores (1-5 pixels wide) are

removed from the mosaics by a process of averaging. Pixels bounding the artifact on a particular line are identified. The DN values of artifact pixels are replaced by the weighted average of the DN values of the two boundary pixels. The weight is the ratio of distance of the artifact pixel from a boundary pixel to the distance between boundary pixels. (This procedure is often referred to as linear interpolation.) Also, the surface sampler arm and housing are removed from the mosaics when they can be replaced by unobscured portions of low resolution images. This procedure is performed by setting a polygonal area of the mosaic to zero DN value. The corresponding low resolution image is geometrically transformed to a high resolution format (and is detilted as well) and the high resolution mosaic and low resolution image are then mosaicked together with the low resolution image given lower priority.

b) Photometric Corrections

Following the above general procedures the solar lighting variations are removed from the scene. These variations are the result of the large changes in phase angle between the sun and camera over the azimuth range. The objective is to obtain an image for which ground material of similar albedo (i.e., reflectivity) and surface normal presents the same DN value regardless of its position in the scene. The solar lighting function is assumed to be a multiplicative function of detilted camera azimuth only. Although not a "true" photometric correction, this approximation is found to perform the desired correction within adequate ranges. An empirical approach to the determination of the function is taken. Test patches on the surface, which are flat and without large rocks or noticeable surface texture, are chosen in the mosaic quadrants at

intervals of approximately every twenty degrees azimuth. The average DN value of each test patch is determined. For test patch i , let the average DN value be D_i . Then each sample at the (detilted) azimuth of test patch i is multiplied by $128/D_i$ to give the corrected DN value. The correction for pixels at azimuth value intermediate between test patch azimuths is calculated by linear interpolation (or extrapolation), using the nearest test patch correction values. After the four quadrants have been corrected for solar lighting effects, they are mosaicked together in a manner analogous to that described above.

c) Geometric Corrections

The geometric transformation is carried out as part of the preparation step on each individual image. The camera geometric distortions may be separated into two types - optic path distortions and camera system distortions. The optic path distortions are those which affect a light ray after it passes the camera window, such as PSA rotation, PSA off-axis effect (coning distortion) etc. Camera system distortions (i.e., rotation and offset) relate to the way in which the cameras are mounted on the Lander. The geometric transformation that is performed in generating the mosaics includes a correction for the optic path distortions, but does not correct for the rotational distortions of the camera system. Instead the rotational distortion correction is replaced by a rotation which removes Lander tilt from the images. As a result, the mosaics retain a small absolute error in azimuth and elevation values, relative to the values which appear in the fiducial annotations on the images. The error may be characterized as a shift of the picture in one direction. The magnitude of the shift is between 12 and 25 pixels depending on the camera. The direction of the shift is a slowly varying function of camera azimuth.

The absolute geometry error, to the nearest pixel, for each mosaic is as follows:

L1C1	=	22 pixels
L1C2	=	5 pixels
L2C1	=	23 pixels
L2C2	=	7 pixels

These errors are primarily due to the camera bolt-down errors which are related to the manner in which the cameras are mounted on the Lander.

The following procedure could be used to remove the residual geometry error and to transform to undetilted, LACCS, coordinates. This is the same method that is used by the computer program RANGER (8) to obtain photogrammetric information from the mosaics.

A pointing direction is calculated for an image point. The detilt rotation is removed and then the camera system rotational distortion is removed, by use of a camera specific rotation matrix. The resultant vector is then used to calculate the corrected azimuth and elevation.

$$(\text{IPL line, IPL sample}) \Rightarrow (\text{az, el}) = (a, e)$$

$$a = \text{start az} + 0.04 * (\text{IPL sample} - 1)$$

$$e = \text{high el} - 0.04 * (\text{IPL line} - 1)$$

$$\vec{V} = \begin{pmatrix} \cos a \cos e \\ \sin a \cos e \\ \sin e \end{pmatrix}$$

$$\vec{S} = (T) \vec{V} = \begin{pmatrix} s_1 \\ s_2 \\ s_3 \end{pmatrix}$$

$$s_1 = \cos a' \cos e'$$

$$s_2 = \sin a' \cos e'$$

$$s_3 = \sin e'$$

$$e' = \sin^{-1} (s_3)$$

$$a' = \cos^{-1} (s_1 / (s_1^2 + s_2^2)^{1/2}) + a_0$$

$$\text{where } a_0 = 170.5^\circ \text{ for camera 1}$$

$$= 5.5^\circ \text{ for camera 2}$$

\vec{V} and \vec{S} are unit vectors,

and (T) is a 3 x 3 orthonormal rotation matrix which transforms from the detilted image system into the CACCS geometrically correct camera command system.

The following rotation matrices are to be used for the four cameras:

$$L1C1; \quad T = \begin{pmatrix} +0.0314098 & -0.0429461 & -0.9985836 \\ -0.9993851 & +0.0142150 & -0.0320465 \\ +0.0155712 & +0.9989761 & -0.0424732 \end{pmatrix}$$

$$L1C2; \quad T = \begin{pmatrix} +0.0307278 & -0.0413363 & -0.9986728 \\ -0.9995210 & +0.0023134 & -0.0308497 \\ +0.0035855 & +0.9991425 & -0.0412454 \end{pmatrix}$$

$$L2C1; \quad T = \begin{pmatrix} +0.1329880 & +0.0517036 & -0.9897681 \\ -0.9910388 & +0.0195218 & -0.1321389 \\ +0.0124900 & +0.9984715 & +0.0538364 \end{pmatrix}$$

$$L2C2; \quad T = \begin{pmatrix} +0.1322667 & +0.0518658 & -0.9898563 \\ -0.9912130 & +0.0082630 & -0.1320151 \\ +0.0013321 & +0.9986196 & +0.0525030 \end{pmatrix}$$

3. Table of Camera Events Used in Mosaics

The following tables list the camera events used to create each quadrant of each mosaic in the order of decreasing priority.

L1.C1.Am (L1982)

Q1	Q2	Q3	Q4
11A154	11A154	11A156	11A156
11E051	11A129	11A129	11A157
11A111	11A097	11E022	11A158
11A025	11A078	11A097	11E064
		11A022	11A023
		11A079	11E129
		11A078	11E052
		11A048	11A022
		11B226	11E053
			11B226
			11E093
			11B225
			11B219
			11E224
			11A097
			11C039
			11B225

L1.C2.Am (L1967)

Q1	Q2	Q3	Q4
12A112	12A116	12A125	12E063
12E054	12A112	12A155	12A125
12A010	12A107	12A116	12A110
12B128	12A010	12A107	12A068
12A059	12A108	12E056	
12A124	12A003		
12A003	12E056		
12E060	12B055		
12A116	12B207		
12C042	12A103		
12C043	12A124		
12C044			
12B203			

L1.CL.PM (L1957)

Q1	Q2	Q3	Q4
11A174	11A143	11A132	11E036
11A173	11A251	11A133	11E037
11E073	11A250	11A137	11A017
11E229	11A174	11E059	11A114
	11A144	11E050	11A141
	11E050	11A051	11A030
	11E098	11A114	11A127
		11E037	11E059
		11A127	11A132
		11A143	11A051
		11A144	11A137
		11A251	11E067
		11E220	11A132
		11E223	11E120
			11E165
			11C033

L1.C2.Pm (L1958)

Q1	Q2	Q3	Q4
12A119*	12A238	12A165	12A255
12A140	12A211	12A164	12B016
12A119*	12A212	12A153	12B000
12A135	12A153	12A238	12A235
12A212	12A119	12B000	12A165
12B227	12A152	12A211	12B208
12A119*	12A140	12A152	12B103
12A002	12A135	12B017	12A014
	12B017	12A235	12A043
	12A235	12A237	12C015

* Camera Event 12A119 was used in various forms with and without the sampler arm (by removing the arm and setting DN values to zero). This was done to get the best coverage of the scene in combination the other camera events used. The highest priority use was with the whole event without the sampler arm. The next priority use was the left-hand part of the event. The third priority use was the whole event, including the sampler arm. Similar techniques were used in other quadrants.

L2.C2.Noon (L1986)

Q1	Q2	Q3	Q4
22B004	22A252	22E003	22E003
22B013	22E013	22A253	22E056
22B046	22E057	22A252	22A124
22B045	22E058	22E012	22E020
22B058	22E012		22A002
22E120	22A251		
22C202	22E046		
22C133	22A002		
22C150			
22C162			
22A002			

L2.C1.Pm (L1959)

Q1	Q2	Q3	Q4
21B213	21A139	21A147	21A168
21A127	21A142	21A149	21A161
21A134	21A150	21A075	21A151
21A139	21A147	21A069	21A075
21A023	21A128	21E057	21A111
	21E059	21A044	21A149
		21A128	21E214
		21A052	21A032
		21A110	21A044
		21A031	21A216
		21A132	21E060

L2.C2.PM (L1960)

Q1	Q2	Q3	Q4
22A118	22A148	22A140	22A140
22A255	22A143	22A141	22A135
22A143	22A011	22A104	22A133
22A011	22A163	22A148	22B211
22A046	22A005	22A119	
22A121	22A103	22E090	
22E091	22A119		
22A005	22E215		
22B212	22E091		
22B014	22C178		
22B215			
22A002			

L2.C1.Am (L1983)

Q1	Q2	Q3	Q4
21E010	21A164	21A221	21E009
21E008	21E010	21E034	21E001
21A204	21E054	21E021	21E039
21C098	21E040	21A225	21C036
	21A076	21A222	21A174
	21A077	21E033	21E040
		21E022	21E094
			21E015
			21E093
			21C069
			21A079
			21A050
			21A077

L2.C2.Am (L1984)

Q1	Q2	Q3	Q4
22A205	22A176	22A206	22A027
22E000	22A095	22A038	22A207
22A236	22A205	22A223	22A223
22E002	22A206	22A220	22A105
22E199	22A178	22E231	
22A178	22E061	22A106	
22E061	22A220		
22E025	22A236		
22A097	22E000		
22A002	22E231		

L2.C1.Noon (L1985)

Q1	Q2	Q3	Q4
21A237	21A237	22A221	21A226
21A233	21A225	21E034	21A222
21A125	21E034	21E021	21E022
21A040	21A221	21A225	21A225
	21E021	21A222	21E035
	21C204	21E033	21E033
		21E022	21E021
		21C152	21C153
			21C208

4. Terminology, Labelling and Fiducial Annotation

The mosaic negatives have the following general form. At the top and bottom of the image is a 16 step gray scale. Beneath the gray scale at the top of the image are two sets of rulings. The upper one is labeled 'az' and specifies the local Mars azimuth of the scene clockwise from north. Beneath this scale is a scale labeled IPL sample no. An identical scale is beneath the image. This refers to the sample number in the digital image data set. The IPL sample no. increases from left to right. To the left of the image are two sets of scales. The leftmost of these is labeled 'EL' and specifies the elevation of the detilted image. To the right of this scale is a scale labeled IPL line no. An identical scale appears to the right of the image. This refers to lines of data or data records in the data set. The IPL line no. increases in the downward direction. The pixel in the upper left corner has the IPL coordinate (1,1).

Beneath the image, two sets of annotation appear. The smaller annotation refers to a specific image in the collection which was used to generate the mosaic. This annotation is of no interest to the general user. The larger annotation identifies the mosaic, specifying, in order, the lander (L1 or L2), the camera (C1 or C2), the time of day (AM, Noon, PM), and which quadrants (e.g. Q1+Q2, Q2+Q3, etc.) comprise the mosaic. The IPL PIC ID is a designator used to uniquely identify a photoproduct generated in IPL. All inquiries concerning a print should include the IPL PIC ID designator.

5. Magnetic Tape Storage

In addition to being available through the NSSDC as photoproducts, the

mosaic data sets are stored in digital form on a series of magnetic tapes. The tapes are recorded on 9 track tape drives. Each image is stored as a separate file. Every file begins with a variable number of label records followed by the actual image. Each label record is 360 bytes in length, and is comprised of 5 logical labels of 72 bytes each. The last byte (byte 72) of each logical label consists of an EBCDIC character, either 'C' or 'L'. A 'C' indicates that another logical label follows, while an 'L' indicates that this is the last logical label. If the last label record contains fewer than 360 bytes, it is padded on the right. The label records contain EBCDIC information which is formatted and displayed at the bottom of a masked print of the image. A more detailed explanation of the label format is contained in ref. (2). The first logical label of the first label record contains information relating to the size of the image. Bytes 33-36 contain a four character right adjusted EBCDIC format integer which specifies the number of lines in the image. Bytes 37-40 similarly contains a number which specifies the number of picture elements per image line.

The image is stored following the label records. Each image line is stored as one record. The data is available either recorded at 800 BPI or 1600 EPI. The 800 BPI tapes each contain one two-quadrant mosaic (either quadrants 1 and 2, 2 and 3, or 3 and 4) with record lengths equal to 4350 bytes and 1852 records (not including the label records). The 1600 BPI tapes each contain a complete mosaic of four quadrants with record lengths equal to 8650 bytes and 1852 records for the imagery data. The following is a list of available tapes.

TAPE LIST

Tape Number	Contents	Density (EPI)
✓DNS 001	L1.C1.AM.Q1 + Q2	800
DNS 002	L1.C1.AM.Q2 + Q3	800
✓DNS 003	L1.C1.AM.Q3 + Q4	800
DNS 004	L1.C2.AM.Q1 + Q2	800
DNS 005	L1.C2.AM.Q2 + Q3	800
DNS 006	L1.C2.AM.Q3 + Q4	800
DNS 007	L1.C1.PM.Q1 + Q2	800
DNS 008	L1.C1.PM.Q2 + Q3	800
DNS 009	L1.C1.PM.Q3 + Q4	800
DNS 010	L1.C2.PM.Q1 + Q2	800
DNS 011	L1.C2.PM.Q2 + Q3	800
DNS 012	L1.C2.PM.Q3 + Q4	800
FNS 001	L2.C1.AM.Q1 + Q2	800
FNS 002	L2.C1.AM.Q2 + Q3	800
FNS 003	L2.C1.AM.Q3 + Q4	800
FNS 004	L2.C2.AM.Q1 + Q2	800
FNS 005	L2.C2.AM.Q2 + Q3	800
FNS 006	L2.C2.AM.Q3 + Q4	800
FNS 007	L2.C1.NOON.Q1 + Q2	800
FNS 008	L2.C1.NOON.Q2 + Q3	800
FNS 009	L2.C1.NOON.Q3 + Q4	800
FNS 010	L2.C2.NOON.Q1 + Q2	800
FNS 011	L2.C2.NOON.Q2 + Q3	800
FNS 012	L2.C2.NOON.Q3 + Q4	800
FNS 013	L2.C1.PM.Q1 + Q2	800
FNS 014	L2.C1.PM.Q2 + Q3	800
FNS 015	L2.C1.PM.Q3 + Q4	800
FNS 016	L2.C2.PM.Q1 + Q2	800
FNS 017	L2.C2.PM.Q2 + Q3	800
FNS 018	L2.C2.PM.Q3 + Q4	800

DNS 013	L1.C1.AM.Q1 + Q2 + Q3 + Q4	1600
DNS 014	L1.C2.AM.Q1 + Q2 + Q3 + Q4	1600
DNS 015	L1.C1.PM.Q1 + Q2 + Q3 + Q4	1600
DNS 016	L1.C2.PM.Q1 + Q2 + Q3 + Q4	1600
FNS 019	L2.C1.AM.Q1 + Q2 + Q3 + Q4	1600
FNS 020	L2.C2.AM.Q1 + Q2 + Q3 + Q4	1600
FNS 021	L2.C1.NOON.Q1 + Q2 + Q3 + Q4	1600
FNS 022	L2.C2.NOON.Q1 + Q2 + Q3 + Q4	1600
FNS 023	L2.C1.PM.Q1 + Q2 + Q3 + Q4	1600
FNS 024	L2.C2.PM.Q1 + Q2 + Q3 + Q4	1600

The first 0 (zero) in the number following either DNS or FNS is replaced by a number 0 to 9, indicating the copy number. D indicates that the contents refer to Lander 1 and F to Lander 2. N means that the data source from which the image is derived is the EDR (Engineering Data Record).

Inquiry about the digital data can be made to the Data Library at the Jet Propulsion Laboratory (JPL), Pasadena, California (213-354-7916).

References

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