1-1-2010

The Mars Viking Lander Experimental Data Record: an Examination of Digital and Analogue Image Objects Within a Museum of Photography Collection

Paul L. Pegnato
Ryerson University

Figure 1. A reproduction of the leader section MTPS Photo Product Label from NASA's Viking Project Experimental Data Record - EDR#1 image roll containing 141 image frames acquired from Viking Lander I in 1976. Image courtesy of George Eastman House, 2010.

THE MARS VIKING LANDER EXPERIMENTAL DATA RECORD:

AN EXAMINATION OF DIGITAL AND ANALOGUE IMAGE OBJECTS WITHIN A MUSEUM OF PHOTOGRAPHY COLLECTION

by

Paul L.G. Pegnato

Rochester, New York

August 24, 2010

A thesis

presented to Ryerson University

in partial fulfillment of the

requirements for the degree of

Master of Arts

in the Program of

Photographic Preservation and Collections Management

Toronto, Ontario, Canada, 2010

Author's Declaration

I hereby declare that I am the sole author of this thesis.

I authorize Ryerson University to lend this thesis or dissertation to other institutions or individuals for the purpose of scholarly research.

I further authorize Ryerson University to reproduce this thesis by photocopying or by other means, in total or in part, at the request of other institutions or individuals for the purpose of scholarly research.

Abstract

Using a set of photographic print rolls containing over 4,000 image frames of the Martian landscape produced by NASA from images obtained by cameras mounted on the Viking Lander I and II spacecraft in 1976, and a companion CD-ROM set containing replicates of Viking's visual data, this thesis will explore the photographic technologies and the image processing procedures used to create NASA image products for scientific research. It will also examine the relationship between the photographic rolls and the original digital entities on the CD-ROMs and explore why such science-based photographic objects should be collected by a museum of photography.

Acknowledgments

I would like to thank my first reader Marta Braun for her time, support, eye for detail and helpful suggestions, and Thierry Gervais for his assistance and feedback as my second reader. I am grateful to Jessica Johnston and Jamie Allen for their continued enthusiasm, kindness, ideas and support, and for putting two-and-two together by suggesting I take a look at the Mars Viking Lander image rolls. Alison Nordström deserves thanks for her advice on how best to approach the project and for our many insightful discussions. I wish to thank Jessica McDonald for her help as an editor and proofreader, and for the invaluable instruction and advice she provided in her research course at George Eastman House. I extend my thanks to Barbara Puorro Galasso for providing photographs of the Mars Viking Lander image rolls. I would like to thank the faculty and staff associated with the Photographic Preservation and Collections Management program at Ryerson University and George Eastman House for their help and willingness to answer endless questions. My thanks also go to my colleagues in the PPCM program for sharing their ideas and for their friendship. Finally, I must thank Karen M. Caulfield for her general patience, especially in reviewing rough drafts and providing feedback on my raw ideas, and for her dedicated support in an infinite number of ways.

Dedicated to C.V.P. and G.M.P. who started my journey of exploration

Table of Contents

List of Illustrations

Introduction

The images of the surface of Mars first captured in 1976 and 1977 by twin panoramic facsimile point-scanning cameras mounted on each of NASA's two Viking Landers represent the culmination of a progressive series of missions dedicated to the visual investigation and exploration of the "red planet" which began with the launch of NASA's Mariner orbital probes in 1964. The Viking Lander images are a unique visual record, a "first" in the history of man. Viking's images are the result of a complex imaging process—a process that involved planning and programming camera event sequences to be performed by each of the Landers' stereoscopic cameras. The encoded image data acquired was then transmitted to Earth to be decoded and reconstructed as readable images, constructing a visual resource and data set of the entire Viking Experimental Data Record for extensive research and analysis.

This thesis will consider examples of two types of image products generated from the data set of NASA's Viking Mission Experimental Data Record—the Jet Propulsion Laboratory's (JPL) photographic image rolls and the NASA Viking "Mission to Mars" two-disc CD-ROM set. It will examine the Viking Lander images from the museum's perspective, establishing the possible motives for adding these specific science-based photographic objects in a photography museum collection—in this case study, the George Eastman House photographic collection. The first image product examined, image rolls acquired by George Eastman House through a donation from Chris Reutershan in 2009, consists of over 4,000 Viking Lander images printed across twenty-four individual black-and-white Kodak paper-based photographic rolls. The image rolls were produced by the JPL's Image Processing Laboratory (IPL) from master film negatives, generated from transmitted image data originating from the surface of Mars. The image data was processed, stored to magnetic media and printed as hard copy output on image setters at the IPL in 1976 and 1977. The second image product, the set of NASA Viking Mission to Mars CD-ROMs, was acquired in a separate transaction following the accession of the Reutershan Viking Lander Photograph Collection. Purchased by the Photography department of George Eastman House from the planetary science section of NASA's National Space Science Data Center web site (http://nssdc.gsfc.nasa.gov/cd-rom/cd-rom.html), this "virtual" image product consists of an archive of raw digital image data files on two commercially produced CD-ROMs containing Viking Lander I and II's complete "Experimental Data Record" (EDR).

An EDR is defined by the authors Wall and Ashmore in NASA Report Number RP-1137 as the entire digital data set of a specific space project. The digital data set includes the original digital image data stored on magnetic tapes received on Earth and the photographic products on which images have been reconstructed by the Image Processing Laboratory in Pasadena, California.[1] EDR photographic products are "primarily a series of roll products" made by the IPL which include duplicate film negatives used to produce film positives and positive paper-based Strip Contact Prints (SCPs,) such as the twenty-four photographic rolls of the Reutershan collection, enlarged prints, or 101.6 x 152.4-millimetre (4 x 6 inch) microfiche cards.[2] David Deats, supervisor of black-and-white image processing at the JPL Image Processing Lab during the Viking Mission, explained that copies of the EDR image archive stored on 9-track magnetic tape reels and EDR photographic products were disseminated to image investigators and Viking

---

1. NASA, Scientific and Technical Information Branch, *Conclusion of Viking Lander Imaging Investigation: Picture Catalog of Experiment Data Record*, by Stephen D. Wall and Teresa C. Ashmore, NASA Reference Publication RP-1137 (Washington, DC: National Aeronautics and Space Administration, Scientific and Technical Information Branch, 1985), vii, 19.

2. Ibid., 20.

Lander Imaging team members at eighteen Regional Planetary Image Facilities, or "RPIFs," located in the United States and Europe.[3]

The images obtained and transmitted from the Viking Landers are a notable technical achievement in the history of photography, however, the historical mark made by the Viking Mission is primarily associated with the mission's principal objective of definitively answering the question posed since the eighteenth century: does life exist on Mars? As noted in NASA's 1975 pre-mission press kit, the "gradual tendency developed among scientists [is] to be very sceptical of the likelihood [of life on Mars]."[4] The biological and visual data returned to Earth proved the sceptics right: no conclusive evidence was found confirming life on Mars. However, Viking's on-board instruments and cameras provided data which significantly advanced planetary science and achieved, as the first mission to "soft land" a spacecraft on the surface of another planet, a "first" in the history of space exploration.

Like many of NASA's missions, the Viking project, initiated in 1968, is an example of the ingenuity, skill, and teamwork necessary to push the limits of engineering and communication technologies of the time. A week after Viking I's touchdown on August 20, 1976, the editor of the journal *Science,* Philip H. Abelson, gave a sense of scale to the challenges NASA engineers and scientists had to face. "In a spacecraft with about 1,450,000 parts operating in a hostile environment," he wrote, "it was essential to build in the capability of meeting many contingencies and to provide a large number of redundancies to cope with unpredictable

---

3. David Deats, conversation with the author, February 24, 2010.

4. Robert Godwin, ed., *Mars: The NASA Mission Reports* (Burlington, ON: Apogee Books, 2000), 118, 175.

failures."[5] With the exception of one instrument designed for recording seismic activity aboard Viking I which remained inoperative, the Landers performed in near flawless manner and continued to collect and transmit data long after their primary missions had been completed.[6] The strategic goals of the Viking Mission were to interact remotely from Earth with Viking's Orbiter and Lander spacecraft to acquire, record, and receive transmissions of experimental data. The mission included a broad series of experiments focused on planetary, chemical, and geological sciences which involved instruments in addition to the photographic equipment aboard Viking's orbital and landing crafts. From 1976 through Viking I's last transmission from the Mars surface in 1982, instruments gathered and recorded data on Mars's seismic activity, soil chemistry and composition, atmospheric particles and gases, magnetic field properties and meteorology.[7] The resulting data was used to expand scientific knowledge of planetary bodies and further refine technologies and instruments for future Mars and space exploration missions.

The scope of this study will not allow for a discussion of full technical details behind the systems and equipment used for image acquisition, or an in-depth breakdown of the multi-tiered image processing systems employed by the JPL's Image Processing Laboratory to reconstruct image data into the variety of available photographic products it was capable of producing. Rather, it will attempt to provide summary explanations to provide the reader with enough knowledge to recognize the scientific innovation behind, and significance of, the technical systems employed during the Viking Mission. The core technical information provided in this paper will allow the reader to understand the components utilised in the Viking Mission image

---

5. Philip H. Abelson, "Viking 1," *Science* 193, no. 4255 (August 27, 1976): 723.

6. United States, National Aeronautics and Space Administration, *NASA Facts: Viking Mission to Mars*, NASA Facts NF-76 (Pasadena, CA: Jet Propulsion Laboratory California Institute of Technology, 1988), 1, 6.

7. Ibid.

experiments—the cameras, data transmission, data storage, and image processing systems involved. With this information at hand, the reader may begin to interpret and recognize the relevance of the text-based image data or Camera Event Record, accompanying each image frame—a precursor to metadata labels commonly used in digital imaging systems of today. The data presented in each Camera Event Record provides specific, critical supplementary information that both informs and establishes the significance of the Viking images within a photographic collection.

With an understanding of the origins and content of the Mars Viking Lander images, this paper will consider the perceptions of the role of scientific photography as an essential and valuable component in extending the depth, richness and historic relevance of an institutional photography collection. Additionally, this thesis will argue for the values of possessing, whenever possible, non-derivative digital replicates of the authentic record (or original image data file,) using the example of the raw digital image files acquired on the NASA CD-ROMs. The raw image files contained on the NASA CD-ROMs are an example of how the authentic digital record may supplement, add meaning and extend alternative access options to images that are difficult to view as is the case with the photographs found on the Viking image rolls.

This thesis will also demonstrate that as the first photographs returned from the surface of another planet, the NASA Viking Lander images are important to the photography collection of George Eastman House as visual evidence of a historic event and as an example of a new image technology within the history of photography. As scientific photographs, the Viking images enhance and build upon the relevance, value and scope of an institutional collection dedicated to telling the story of photography. The value of the collection of Viking Lander images is further enhanced by accompanying the photographic prints contained on the NASA/JPL-produced image rolls with authentic copies of the raw image data held on the NASA CD-ROMs, the records of authenticity from which the prints were produced. Through both, a comprehensive and authentic photographic archive of the Mars Viking Lander images can be preserved and made accessible for both research and exhibition purposes by George Eastman House. The Viking image products can be used to educate and further inform all audiences not only of the Mars Viking Mission "camera events," but also to present the foundations of digital photography image processes, practices, and preservation.

Literature Survey

Evaluating the historic significance of the 1976 Viking Lander images, their importance to the George Eastman House photography collection and the relationship between the photographic print and the digital image source, requires an understanding of the origin and use of the two Viking image products under investigation in this case study: the first, a set of twenty-four Strip Contact Print image rolls generated by the Jet Propulsion Laboratory (JPL) and the second, the CD-ROM two-disc set holding the complete image archive of Viking Lander I and II's Experimental Data Record produced by NASA's Planetary Data System (PDS). Both photographic products serve as delivery mechanisms derived from the same raw image data originally acquired by the Viking Lander cameras during their primary and extended missions. Tracing the origins of both products involves following a trajectory beginning with image acquisition on the surface of Mars, moving to data telemetry transmitted across space to NASA's Earth-based Deep Space Network and ending finally through image processing by the Viking Lander Imaging Science Team's First-Order image processing systems. The history of both objects must be defined in terms of the digital technologies employed to obtain the images, the audience the photographic products were designed for, and the means by which the images are accessed and considered today—over thirty years after the original primary mission was concluded.

Robert Godwin's publication "Mars: The NASA Mission Reports" usefully compiles the press kits and mission reports produced by NASA into a single volume, providing a context for all the Mars exploration missions both before and after Viking. It is one of several examples of materials published by NASA which comprehensively detail every aspect of the technologies, equipment, and processes utilised to produce the photographic record collected by the Viking Landers.

NASA publications specific to the Viking Mission present not only a historic account of the Viking Mission's achievements in advancing planetary, atmospheric and geological sciences, but more critically, serve as indispensable guides from which to begin to interpret and decipher the perplexing camera event labels and visual content contained on the Viking image objects under investigation here. An essential example is found in the brief essays and explanatory content accompanying the diagrams, illustrations and Viking Lander photo-reproductions in *The Martian Landscape* (1978), collectively authored by members of the Viking Imaging Team who took part in the Viking Lander primary mission. The text in this publication serves as a primer for understanding the content and meaning of the Mars Viking photographs contained on the image rolls and the image files contained on the NASA CD-ROM set. *The Martian Landscape* also offers clarification for interpreting those images which do not obviously depict the Martian landscape—such as calibration targets, exposure and system test images and images which document Viking's Sampling Arm experiments.

Numerous NASA reports documenting the findings of the individual experiments conducted by Viking I and II, including detailed reports from the Viking Lander imaging experiments, are accessible through NASA's National Space Science Data Center (NSSDC) master catalogue portal website.[8] Here we find Stephen D. Wall and Teresa C. Ashmore's NASA report RP-1137 from 1985, "Conclusion of Viking Lander Imaging Investigation: Picture Catalog of Experiment Data Record," which comprehensively outlines the organisation and structure of the visual data record set obtained by the Viking Lander camera systems during the

8. The NSSDC website may be found at: http://nssdc.gsfc.nasa.gov/nmc/PublicationQuery.jsp

Viking Mission. The report provides extensive details related to the Experimental Data Record photographic products generated by the JPL, but most crucially, contains helpful documentation and a key which defines and describes the terms, abbreviations and values used in the camera event data surrounding each photograph on the image rolls. The same camera event data is also incorporated into the interface of the CD-ROM Experimental Data Record image archive examined in this case study.

Elucidating the complex varieties and formats of Viking image data, the document "Catalogue of EDR Tape Products" produced by Susan K. LaVoie, Institutional Principal Investigator at the JPL Planetary Data System Imaging Node, was originally designed as a finding aid to assist users in locating EDR image data contained on individual 9-track magnetic tape reels, the original storage media used by JPL for Viking data. The report describes restoring and migrating image data across different file formats and magnetic tape storage formats and incorporates excerpts of Wall and Ashmore's report RP-1137, providing a description of the range of image products the JPL's Image Processing Lab produced from the original raw Viking image data including EDR images recorded on the photographic image rolls, high resolution compiled mosaic prints and stereographic projections. However, it is the Viking Lander Science Team's collaborative paper "Processing the Viking Lander Camera Data," (Elliott C. Levinthal, et al.,) published in September, 1977 in the *Journal of Geophysical Research* which provides the most thorough breakdown of the entire camera data processing workflow from image acquisition to image product delivery. The article also includes details of the various image products generated by first-order and second-order image processing procedures. Levinthal's workflow charts allow the photographic image rolls to be specifically identified within one of the JPL's many image product categories. Levinthal's nine-page article provides a technically savvy user of either the photographic image rolls or CD-ROMs with a core foundation for understanding and drawing meaning from the images and data presented in both products.

Working from the descriptions of image content, data definitions and organisation structure provided by the NASA reports and Levinthal's articulation of the process workflow from image acquisition to product output, it is possible to consider the relationship between the physical photographic prints on the image rolls and the corresponding virtual digital source from which each image is produced. In this case the authentic records are exact copies of raw data files from the EDR image archives of Viking I and II stored on optical media—a commercially available CD-ROM available from NASA. Bertrand Lavédrine's *Guide to the Preventative Conservation of Photographic Collections* (2003) offers insightful information and useful departure points for issues concerning digital entities as definitive records of authenticity. Lavédrine offers a comprehensive view of the critical issues concerning the preservation of digital entities and the prospective difficulties caused by technical obsolescence in aging hardware and software. Lavédrine also presents a framework from which to consider whether copies of born-digital entities, unlike digital surrogates of analogue works, may be of inferior, derivative and diminished value.

Cameron and Kenderdine's *Theorizing Digital Cultural Heritage: A Critical Discourse* (2007) provides a basis from which to consider the value, meaning and presence of digital objects within cultural heritage institutions. Essays within this publication develop ideas about the divide between analogue, or print objects, and digital "surrogates" or copies. In the case of the Viking images, each is an authentic record, a digital entity possessing properties similar to those associated with a rare original work of art.

In terms of investigating the integration of scientific photography into the space of cultural institutions, Corey Keller's 2008 *Brought to Light: Photography and the Invisible, 1840-1900* and Ann Thomas's 1997 collection of essays in *Beauty of Another Order: Photography in Science,* serve as a starting point in considering scientific photography beyond its obvious evidential value, but also in terms of its cultural, social and political significance. These attributes, along with the Viking images' relevance within the history of photography, begin to demonstrate how scientific photographs may contribute to the scope and value of an institutional collection such as that of George Eastman House. The essays in *Brought to Light* refocus an understanding of the fundamental concepts of scientific photography, for example, the photograph as evidence and proof of observation. Additionally the essays position scientific photography as a fusion of technology and aesthetics. In the case of the Viking Lander images, this fusion requires optics, engineering, hardware, software, communications technology and image processing techniques to interlock with precise orchestration in order to create relevant and readable visual records from an extremely remote and alien location.

The essays in Thomas's *Beauty of Another Order*, further expand on the ideas of the fusion of technology and aesthetics, suggesting that scientific photography, especially when placed within a cultural institution, has a history of inspiring and influencing creative non-scientific photographic work. Thomas writes of the "continuum of ideas" communicated in scientific photography, and essay contributor Mimi Cazort employs the term "cultural continuum." Both phrases express a concept applicable to and implied within the objectives and missions of cultural institutions—to not only disseminate new information, but as in the case of the Viking images, to educate and expand a viewer's understanding of the subject from a historical, technological and cultural point of view.

Description of the Viking Lander Objects – Cameras, Image Rolls and the NASA CD-ROMs

NASA's post-mission report, *Viking Mission to Mars*, summarizes the visual record captured by the Viking cameras and the content of the Viking image products: "The Landers provided the first close-up look at the surface, monitored variations in atmospheric opacity over several Martian years, and determined the mean size of the atmospheric aerosols."[9] Professor Raymond E. Arvidson, leader of the Lander Imaging Flight Team, adds a further summary of the visual record acquired by Viking:

> The Lander imaging experiment viewed the scene surrounding the Lander, the surface sampler and other parts of the Lander, the sun, Phobos, and Deimos to provide data for operational purposes and geological and meteorological investigations. A total of 3,043 images were returned by the Viking 1 Lander, for a total of 6585 images returned by both Viking Landers.[10]

As well as indicating the quantities of visual data Viking collected to form a comprehensive Experimental Data Record, Arvidson also demonstrates the scope and range of practical applications resulting from the image investigations conducted by Viking's camera "eyes"—results that could be used during and long after the mission. The visual record aided scientists with physical property investigations, which when combined with other non-image data such as soil analysis, meteorological and magnetic readings, formed conclusive reports contributing to the advancement of planetary sciences.

---

9. Robert Godwin, ed., *Mars: The NASA Mission Reports*, 181.

10. NASA, "NASA-NSSDC-Experiment-Details: Lander Imaging," National Space Science Data Center http://nssdc.gsfc.nasa.gov/nmc/experimentDisplay.do?id=1975-075C-06 (accessed May 20, 2010).

The technology required to capture and transmit the visual record of the Landers' image investigation experiments had to incorporate accurate optical components, flexible interoperability, and consistent reliability. Viking's facsimile point scanning cameras were built by the ITEK Corporation and were based on a design modification and re-engineering of Eduard Belin and Arthur Korn's photographic image transmission system, phototelegraphy, developed in 1908 to send images by telegraph or telephone.[11] The Viking cameras utilised photo sensitive diodes to capture an image in an array of pixels on which brightness values were converted to voltage signals which in turn were converted from analogue to digital values to create digital image frame data.[12] The digital image data could be optionally transmitted to Earth directly from the Landers in real time as the image was acquired, relayed through the Viking Orbiters, or stored temporarily on the Lander's on board magnetic tape drive for later transmission.[13] Transmitted image data was received on Earth by the Deep Space Network receiving stations, recorded onto magnetic tape, and relayed to the JPL's Viking Mission Control and Computer Center in Pasadena, California, for image decoding and reconstruction.

An image was produced by recording an elevation scan of successive individual vertical lines divided into 512 pixels from bottom to top using a pivoting mirror nodding up and down, line-by-line, inside the camera housing. The mirror reflected the Martian scene through a lens focusing light on one of twelve possible photodiodes assigned to capture a scene in high or low resolution. At the completion of each vertical line scan, the camera body rotated in an incremental horizontal direction (otherwise known as 'azimuth' or horizontal field of view),

---

11. Eastman Kodak Company, *Milestones in Photography / Eastman Kodak Co.* (Rochester, NY: Kodak, 1950), 5.

12. Thomas A. Mutch et al., *The Martian Landscape* (Washington, DC: Scientific and Technical Information Office National Aeronautics and Space Administration, 1978), 7.

13. NASA, Scientific and Technical Information Branch, *Conclusion of Viking*, 10.

equal to the single pixel width (or resolution step size), to record the next vertical line and gradually build the image panning from left to right.[14] Arvidson provides further specifics of the Viking cameras' movement, vertical and horizontal fields of view, mount positions, and stereoscopic capabilities:

> Each image acquired covered a vertical field of 20 deg (high-resolution) or 60 deg (low-resolution, colour, and IR) and a horizontal field that was commandable from 2.5 deg to 342.5 deg in 2.5-deg increments. Images were acquired from 40 deg above the nominal horizon to 60 deg below, and were commandable in 10-deg increments. The cameras were mounted 1.3 m above the nominal landing plane and were capable of viewing two footpads and most of the area accessible to the surface sampler. The two cameras were separated by 0.8 m, and stereoscopic pictures were obtained over most of the scene.[15]

This description not only provides the details of the field of view the cameras could capture, but also describes the metadata that could be recorded with each image. The Imaging Team could select one of twelve possible diodes based on the objectives of the image investigation. Four of the diodes, each with specific focal lengths, were used for high resolution monochromatic white image capture. Viking's high resolution mode captured an instantaneous angular view (or step size) of 0.04° at the pixel level. Three diodes were fitted with filters to record individual colour values of red, green and blue in successive line scans to reconstruct colour images at the lower resolution of 0.12° angular view or step size. A "Survey" black and white diode was used for low resolution panoramic scans; three diodes were designated to record levels in the infrared spectral ranges; lastly, the twelfth "Sun" diode could be selected for solar imaging.[16] A basic familiarity with the specifics of the Viking's camera functionality in Arvidson's and in many of NASA's

---

14. NASA, NASA Scientific and Technical Information Office, *Viking Lander Atlas of Mars*, by Sidney Liebes, Jr. NASA Contractor Report 3568 (Washington, DC 1982), 1. http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19830005765_1983005765.pdf.

15. NASA, "NASA-NSSDC-Experiment-Details," 1.

16. NASA, Scientific and Technical Information Branch, *Conclusion of Viking*, 5.

other published Viking mission reports, provides great assistance in allowing the viewer to interpret and “read” the images on the Reutershan collection image rolls and the digital files on the NASA PDS Geosciences Imaging Node CD-ROMs.

The camera’s functions and the controls used during image acquisition, for example—elevation and azimuth field of view, step size / resolution, gain and offset for exposure control, diode selection, date and time of acquisition—directly relate to the image data parameters used to document the specific attributes unique to each camera event.[17] A formatted Camera Event Record accompanies each image and is a critical element consistently and predominately featured on all photography products and storage media used in the Viking Experimental Data Record. This includes digital data distributed on magnetic tape, photographic prints on the JPL Image Processing Lab’s Strip Contact Print image rolls and the full digital image archive within the directory structures of NASA’s CD-ROMs produced several years after the mission. The NSSDC website, a portal to the permanent archives for NASA space science data, verifies the image content common to the Strip Contact Print image rolls and the NASA CD-ROMs. According to the NSSDC’s “Viking 2 Lander Raw Image EDRs on CD-ROM (PDS)” webpage: “Images include reference and calibration shots, multiple shots through different filters to produce colour images, small sections and close-ups and large panoramic views of the surface. . . . with an attached PDS label which gives the image file structure and instrument parameters.”[18]

---

17. Edward A.Guinness, “Archive of Viking Lander 1 and 2 EDR Images,” in *Viking Lander 1 EDR Images of Mars – USA_NASA_PDS_VL_0001*, CD-ROM, Version 1, (St. Louis: PDS Geosciences Node, Washington University, 1997), VOLINFO.HTM under Lander Camera System. See also: ftp://pdsimage2.wr.usgs.gov/cdroms/viking_lander/vl_0001/document/volinfo.htm#S04

18. NASA, “NASA-NSSDC-Data Collection – Details: Viking 2 Lander Raw Image EDRs on CD-ROM (PDS),” National Space Data Center, http://nssdc.gsfc.nasa.gov/nmc/datasetDisplay.do?id=PSPG-00184 (accessed June 24, 2010).

Each of the twenty-four image rolls in the Reutershan collection varies in overall length based on the number of image frames printed on each roll ranging from 120 to 280 images per roll.[19] The images are a sequential record of camera event data resulting from Viking's image investigation experiments initiated twenty-five seconds after touchdown on the western slopes of Chryse Planitia by Viking Lander I on July 20, 1976, and immediately after Viking Lander II's touchdown in the Utopia Planitia region on September 3, 1976. The width of the image rolls is 127 millimetres (five inches)—the dimension of the Kodak black-and-white matt-finish gelatine-silver paper stock used by the IPL for Strip Contact Roll production. Each image roll is loosely wound on an approximately nine-centimeter diameter cardboard spool requiring the viewer to unroll a segment onto a flat surface in order to examine the individual image frames.[20] A label printed in the blank leader section of each roll is inscribed with a unique identification number, EDR reference number and IPL production date for each roll.[21] Production dates on the Reutershan Collection rolls range from early March of 1977 through late November of 1979.

The Reutershan Collection represents only part of the Jet Propulsion Laboratory's complete set of forty-five photoproduct rolls made available to the Viking Imaging Team during and after the mission in the 1970s and 1980s.[22] NASA's National Space Science Data Center at the Goddard Space Flight Center in Greenbelt, Maryland, holds the complete archive of forty-five image product rolls encompassing 451 camera events obtained by Viking Lander I, labelled as "VL-1," and twenty Lander II rolls including 574 camera events labelled "VL-2."[23]

---

19. George Eastman House, Reutershan Collection inventory list, 2009.
20. Photographic reproductions of the image rolls are available in under Illustrations – Figure 3, page 55.
21. See Figure 1, i.
22. NASA, Scientific and Technical Information Branch, *Conclusion of Viking*, 20-21.
23. Elliott C. Levinthal et al., "Processing the Viking Lander Camera Data," *Journal of Geophysical Research* 82, no. 28 (September 30, 1977): 4412.

Viewing the images on the rolls may not at first match the viewer's expectations of casually browsing through landscape views and rock formations of an extraterrestrial world. Amongst landscape images of the Martian surface are camera reference, calibration and scan verification test images appearing as tightly cropped vertical bands of blacks, greys and whites framed by numerical information, label data, and measurement scales.[24] Only as the viewer scrolls through the images do the relationships, sequencing and associations between images become discernable. In some cases, panoramic views span successive image frames and reveal more familiar visual tropes: boulder strewn terrains; a horizon line splitting the picture plane into foreground and background; or the Viking spacecrafts themselves—the Landers' footpad, housing, antennae, receiving dish and mechanical sampling arm maintaining a fixed presence throughout the visual record. To the viewer, the visual components—a succession of image frames accompanied by a unique Camera Event Record describing the how, what, where and when of each image—are hard copy records of scientific data. The images are output records depicting the results of reconstructed digital data acquired by Viking's point-scanning panoramic cameras—photographic records of specific camera events originating as a set of command parameters programmed by members of the Viking Lander Image Investigation teams on Earth.

Despite the technical appearance of the hard copy images, the "meta" information surrounding each frame provides valuable details related to camera variables, area of image field scanned, exposure details and date and time for each camera event. Once the viewer is familiar with the numeric scales, format, terminology and abbreviations used in the data label record (or Camera Event Report), the image frame can be easily "read," functioning in a similar capacity as a caption. A brief overview of the terms, attributes, elements and numeric scales bordering each

24. NASA, Scientific and Technical Information Branch, *Conclusion of Viking*, 26-7.

image frame is provided below and may be used as an initial guide for translating the data content surrounding the example of a Viking Lander image frame reproduced in Figure 2 (page 29). Figure 2 is the first photograph of Mars, camera event 12A001/000, taken from the Reutershan collection, roll number EDR-1. The Camera Event Record below the image, and linear scales bordering the image, describe the camera event commands and data receipt parameters. For example:

- The date and time of the camera event noted by Earth calendar date and time (EVENT D/GMT), Lander mission day and time from touchdown and Martian solar day, or Sol, and time (LLD/T).
- The Camera Event Label (CE LABEL) identifier—an alpha/numeric ten-digit code, indicating the Viking Lander "1" or "2"; camera "1" or "2" aboard each Lander; the frame count sequence number identified by a letter prefix cycling after a numeric value after every 256 camera events (e.g., A255 is followed by B000) and Sol mission day starting with "000" upon Lander touchdown.[25]
- The azimuth or horizontal field of view within the cameras operational range of 0° to 342.5° degrees just short of a true 360° panoramic view indicated numerically in the data label (as AZIMUTH) and by a linear scale ruled in incremental units (degrees) displayed along the top frame of the image.[26]
- The diode or photo-sensor name selected from twelve possible options including one of four black-and-white high-resolution diodes set at specific focal lengths ("BBC-1", "BBC-2", "BBC-3", or "BBC-4"); a low-resolution black and white survey mode

25. NASA, Scientific and Technical Information Branch, *Conclusion of Viking*, 14.
26. NASA, "NASA-NSSDC-Experiment-Details," 1.

(“SURV” or “SUR”); three colour diodes (“RED”, “BLU”, “GRN”); three possible infrared frequency options (“IRL -1”, “IRL-2”, “IRL-3”) and a specialised “SUN” diode for Sun image investigations.[27]

- The vertical angle image span from the top to the bottom of the frame based on the pointing angle or centre elevation (ELEVATION) of the Viking camera. Values in degrees are either positive or negative for the upper or lower limits based on a value of 0° for the horizon line. Like the azimuth data, the data label indicates values numerically and a linear scale ruled in incremental units is displayed along the left frame of the image.
- The image resolution—(STEP SIZE) indicates the instantaneous angle of view captured by each pixel during the camera event scan—either 0.04° in high resolution, or 0.12° in low resolution often employed for survey views.
- Bordering the perimeters of each image frame, the vertical and horizontal pixel position scales indicate the camera and IPL image output scan lines, up to 512 pixels in the vertical position corresponding to the Viking camera’s image sampling capacity. The horizontal scales indicate scan sample numbers which define image coordinates starting from “0” on the left frame and increasing in value towards the right. This is useful in identifying segments of continuing panoramic views in consecutive image frames given that the image processing software had a maximum horizon output of 901 unique lines per image frame.[28] Each segment repeats the previous 150 lines followed by the next 901 lines of the panoramic image, with an approximate maximum frame width of 1,050 lines. Hence the use of the SEGMENT number designation seen in the data label to indicate a

27. NASA, Scientific and Technical Information Branch, *Conclusion of Viking*, 14.
28. Ibid., 20.

camera event spanning multiple image frames. This is also similar to a “triplet” where three successive image frames of the same scene appear on the image roll differentiated only by shifts in tonal values. Each frame is associated with a colour diode scan equipped with a filter for blue, green and red to produce colour separations for later colour image output.

- An IPL Picture Identifier (IPL PIC ID)—a numeric code, using a date and image number format, is included with the data record of each image. This EDR Order Number was used by image investigators to designate and request specific image segment products from the National Space Science Data Center.[29]

27. NASA, Scientific and Technical Information Branch, *Conclusion of Viking*, 18.

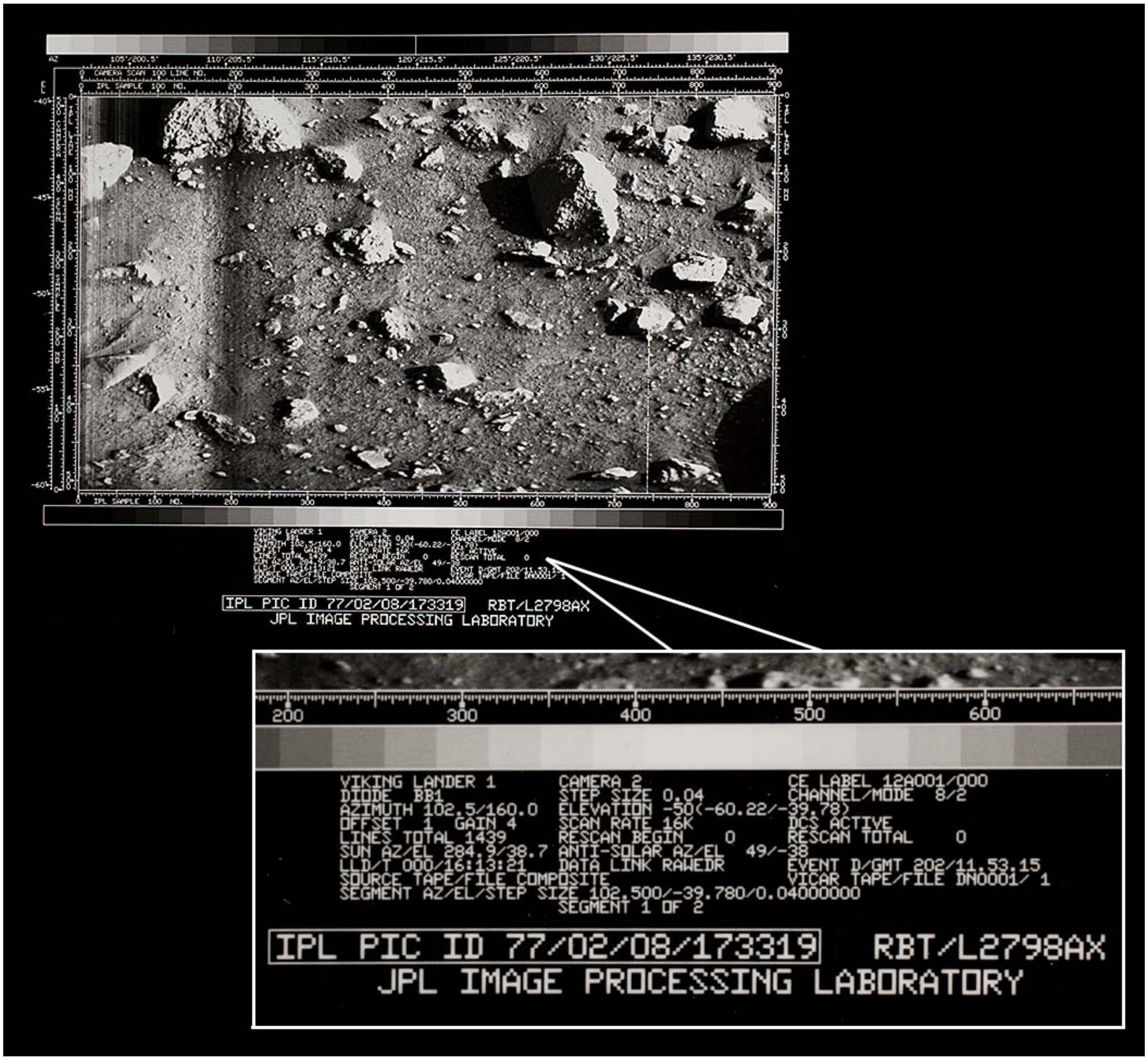


Figure 2. A reproduction of a camera event image frame printed on Viking Strip Contact Print image roll number EDR-2, Reutershan collection at George Eastman House. Note the fiducial scales on the perimeter of the image frame, the Camera Event Record data table and the IPL Picture Identification label below the image and detailed in the magnified inset. The CE label identifier code "12A001/000" of this image informs the viewer that the image was captured by Viking Lander I ("1"), Camera 2 ("2") as the first camera event in the first series of 255 camera events ("A001") captured on the 1st Martian Solar day of the mission ("/000"). Image courtesy of George Eastman House, 2010.

In addition to providing the specific data parameters for each image, the Camera Event Record is also an indicator of the precise operational and processing controls employed by the

Viking Lander Imaging team to acquire, transmit, reconstruct, and disseminate Viking's complete experimental data set. The organisational structure of the data in the Camera Event Record is evidence of the supporting image database framework required to manage, store and preserve Viking Lander image data for both real-time use during the mission and long-term use for ongoing studies by image investigators, academic researchers, scientists outside of NASA's immediate network, and in time by members of the public.

The image processing system employed by the Viking Lander Imaging Science Team is detailed in full in Elliot C. Levinthal's co-authored report, "Processing the Viking Lander Camera Data." The report's abstract describes the team's solution for managing and processing Viking Lander telemetry during the mission in 1976:

> A system was devised for processing camera data as they were received, in real time, from the Deep Space Network. This system provided a flexible choice of parameters from three computer-enhanced versions of the data for display or hard-copy generation. . . . A second order processing system was developed which allowed extensive interactive image processing including computer-assisted photogrammetry, . . . mosaicking, and color balancing using six different filtered images of a common scene. . . .These results have been completely catalogued and documented to produce an Experimental Data Record.[30]

Levinthal's report describes the hierarchical structure of the throughput system used to reconstruct image data received from Mars into a wide range of output products for immediate distribution and derivative products used for long-term image investigation and scientific research. The image processing system also incorporated functional procedures designed to preserve image data using redundant storage systems on magnetic tape at critical processing stages within the workflow. The report features a complex, but logical "waterfall" flowchart illustrating multiple processing steps which begin with transmitted raw image data received by

30. Levinthal et al., "Processing the Viking Lander," 4412.

the Deep Space Network—an infrastructure of tracking stations positioned strategically across the Earth. The data then moves to First-Order Viking Lander Image-Processing (FOVLIP) software and subprograms generating First Order image products. These products include volatile CRT video display, Digifax (facsimile type) prints processed within minutes of receiving data, and photographic copy-prints generated from 5-inch-wide film negatives for distribution within twenty-four hours.[31] Most critically, Levinthal notes that First Order products also include, ". . . digital tapes of raw image data forwarded to the Image Processing Laboratory as the input source which are forwarded to IPL as input to the Second-Order image processing system."[32] The Second-Order-Processing System, operated by JPL's Image Processing Laboratory in Pasadena, California, processed image data through a series of advanced image processing algorithms and filters to yield a diverse range of second generation output products, including the five-inch roll photographic products and again, with storage redundancy in mind, a series of permanent EDR digital tapes on magnetic media.[33] The EDR digital tapes are part of the Second Order products designed for distribution to the Regional Planetary Image Facilities. The tapes contain replicates of the authentic digital record captured by the Viking cameras. Twenty years after the primary and extended Viking mission were completed, the EDR digital tapes were used as the master data source by NASA's Planetary Data System Geosciences Node to create the image archive CD-ROMs described below.

31. Ibid., 4413.
32. Ibid.
33. Ibid., 4412, 4415.

Description of the NASA Viking Lander I and II EDR Image Archive CD-ROMs

The Viking CD-ROM set was produced by Edward A. Guinness, Thomas C. Stein, and Jennifer Herron, members of the Department of Earth and Planetary Sciences, Washington University, St. Louis, Missouri on June 27, 1997, and is currently available to the public through the NSSDC website at a cost of $10 per disc. Similar to the Reutershan Collection image rolls, the Viking Lander two-disc CD-ROM set does not offer instant and intuitive access to the photographic record of the Mars Viking Mission. Instead, the NASA CD-ROM set functions as a simple read-only storage device containing volumes of data organised in a straightforward hierarchical directory structure. Navigating to the "README" directory, a conventional practice in CD-ROM content interaction in 1997, provides access to an introductory text file designed to function as a user's guide and content directory for each of the CD-ROMs. The less patient viewer may intuitively navigate to the "BROWSE" directory where selecting the "INDEX.html" page will launch a "Quick-Look" web browser application to view small low resolution GIF format images. Each image is displayed on a separate HTML page along with the same camera event data seen below the image frame in the Strip Contact Print image rolls. Hyperlinks provide convenient navigation to an HTML data dictionary page which defines camera event data parameter terms.[34] The user may optionally link to an image directory page to navigate more easily between data folders organised by alpha-series (sets of 255 images as noted above) from Camera 1 and 2 on the Viking Landers. The Viking Mission to Mars CD-ROM set also includes detailed and otherwise unpublished documentation about the Viking project, which as noted by the CD-ROM producers at the PDS Imaging Node, ". . . includes mission, spacecraft, and instrument reports, such as calibration reports, flight operations and science team reports, and the

34. A screen capture of the Quick-Look interface is available under Illustrations–Figure 4, page 56.

mission history. . . . details of the mission that would not typically be available through published literature."[35] Documentation also includes descriptions of the imaging and data processing technologies used during the Viking mission, as well as the strategic approach used by the PDS Geosciences Imaging Node to preserve and, where necessary, restore the Viking Experimental Data Record. The producers of the Viking CD-ROMs confirm: "Prior to the restoration efforts . . . . the data were stored in formats unique to the each mission with no software tools available to access the data. As a result of the restoration efforts for these data sets, the Node produced CD-ROM volume sets for wide distribution to the science community."[36]

As well as serving as the complete Viking EDR image archive, the CD-ROM set, given its date of original production, demonstrates prescience with regards to current institutional best practices in migration, preservation, and long-term storage of authentic digital image data records. In their introductory notes, the producers describe the origins of the images and data archived on the disc set as the original Viking raw image data: "EDR products . . . copies of images released by the Viking Project. The data were recovered from the original 9-track tapes made for the Lander imaging team."[37] In addition to mentioning the magnetic storage mechanisms first used for the Viking Lander image data, the producers also detail the migration and conversion of NASA's original VICAR image file format used during the mission to an updated NASA image format standard, "PDS," still in use today. The conversion of VICAR image files to PDS demonstrates a migration strategy cognisant of supporting open standards

---

35. Eric M. Eliason, Susan K. LaVoie, and Laurence A. Soderblom, "The Image Node for the Planetary Data System," *Planetary and Space Science* 44, no. 1 (January, 1996): 23.

36. Ibid.

37. Edward A. Guinness, Thomas C. Stein, and Jennifer Herron, *Mission to Mars: Viking Lander 1 EDR Images of Mars – USA_NASA_PDS_VL_0001,* CD-ROM, Version 1, (St. Louis: PDS Geosciences Node Washington University, 1997).

designed to ensure the interoperability of Viking's digital entities on popular computer platforms, software and hardware systems.[38]

NASA's PDS Imaging Node clearly grasps the value, significance and imperatives for safe keeping and preservation of the Viking data collection. The PDS Imaging Node describes its core objectives in preserving data collections from all space exploration missions:

> The Planetary Data System Imaging Node maintains and distributes the archives of planetary image data acquired from NASA's flight projects. . . . The Node provides direct and easy access to the digital image archives through wide distribution of the data on CD-ROM media and on-line remote-access tools by way of Internet services. The data collections, now approaching one terabyte in volume, provide a foundation for remote sensing studies for virtually all the planetary systems in our solar system (except for Pluto). The Node is responsible for restoring data sets from past missions in danger of being lost.[39]

The issues and requirements for preserving, distributing and providing access to authentic digital records can be successfully addressed through a methodical approach based on an understanding of how to best work with original data structures across evolving formats, distribution and storage platforms. With the creation of the Viking CD-ROMS, the PDS Imaging Node met the challenge of responding to the complexities surrounding digital preservation as described by *New York Times* writer Patricia Cohen, who concluded "that archivists are finding themselves trying to fend off digital extinction at the same time that they are puzzling through questions about what to save, how to save it and how to make that material accessible."[40] It may be that the nature of the Viking data eliminated the question of what to save, but the raw camera data remains with

---

38. Margaret Hedstrom, "Research Issues in Migration and Long-Term Preservation," *Archives and Museum Informatics* 11, no. 3-4 (September, 1997): 287-292.

39. Eric M. Eliason, Susan K. LaVoie, and Laurence A. Soderblom, "The Image Node," 23.

40. Patricia Cohen, "Fending Off Digital Decay, Bit by Bit," *New York Times*, March 15, 2010 http://www.nytimes.com/2010/03/16/books/16archive.html (accessed March 16, 2010).

the help of NASA's software tools and proprietary PDS image archive format and continues to be relevant and usable.

In terms of usability, the most useful feature of the NASA CD-ROMs is the opportunity to interact with the Viking raw camera data stored on the CD-ROMs through NASAView, an image archive display software application.[41] NASAView allows users to open and view Viking raw image files, display the full camera event data record, view the image histogram to adjust contrast and brightness and to select a range of palettes to isolate and enhance the image view for specific frequency ranges. The copyright free images may then be exported into external image editing applications as a GIF or JPEG file. This makes it possible for the user—researcher, curatorial or exhibition staff—to generate exhibition quality print reproductions direct from the authentic record, the raw digital image source acquired by the Viking cameras.

In contrast to the CD-ROM disc set, the Image Processing Laboratory's analogue based Strip Contact Print image rolls represent a truly analogue form with properties similar to the reel-to-reel magnetic tapes from which they were created. Access to one specific print requires manually scrolling through a fixed head-to-tail sequence of consecutive image frames printed on the roll. A reference document which lists image frames indexed by EDR image roll volume numbers is an essential reference tool to efficiently locate and view a specific Lander image. NASA's PDS Imaging Node developed and evolved a progressive series of digitally-based "random access" products—interactive digital catalogues using interactive web-based interface tools and applications to provide efficient search, retrieval and access to images within the

41. Note: The application is not available on the NASA CD-ROM set and may be downloaded, as noted in the "AAREADME" file, from the PDS Software Page: http://pds.jpl.nasa.gov/tools/nasa-view.shtml (revised URL as of July 1, 2010.) A screen shot reproduction of the NASAView application interface is available under Illustrations–Figure 5, page 57.

complete Viking EDR image archive. The PDS Imaging Node began with easily distributable CD-ROM media, primarily conceived as an inexpensive portable storage device with few user interactive features, and quickly progressed to the current online web interactive catalogue accessible at the PDS Imaging Node's Planetary Image Atlas website.[42] The site's modified image search and retrieval interfaces demonstrate considerable refinements over the original CD-ROM Quick-Look HTML browser.

As we might expect, the advancement of online interactive and database integration technologies since 1997 have rendered both the CD-ROM products and NASAView software nearly obsolete. On the Planetary Image Atlas, the Camera Event Record also drives the search query parameters in order to retrieve specific Lander images. Users may search for specific images graphically—through an image map, by choosing a section from each Lander's overall panoramic view, by CE label number, by Martian Solar Day or by an advanced search using Camera Event Record data. The user may download image data in a range of image file formats, including: TIFF, JPEG, NASA's proprietary PDS and Viking's original raw image format, VICAR. All of the PDS Imaging Node digital catalogue products, with the exception of the HTML Quick-Look browser, which utilises compressed "thumbnail" preview GIF images, allow users to download and manipulate a copyright-free replicate of the original raw data without compromising the authentic record.

Both analogue and digital image products reserve a prominent position for the display of the camera event metadata—crucial to being able to "read" Viking Lander images and derive meaning whether viewing the image roll or on-screen image products. In researching this paper,

42. The PDS Imaging Node's Planetary Image Atlas for the Mars Viking Lander Image Data may be found at: http://pds-imaging.jpl.nasa.gov/vikingl/vl_images.html. Also see Illustrations—Figure 6, page 58.

the CD-ROM set, undoubtedly a stand-alone product in terms of examining the Viking images from a non-scientific perspective, served initially as an ancillary resource for the interpretation of the images, data, and the image content on the Reutershan collection image rolls. Though the CD-ROMs were used to gather critical information for interpretation of the image objects, as research for this paper continued, the Strip Contact Print rolls became the ancillary resource to the CD-ROMs. This inverse effect may be, in part, a result of the impractical access to images and laborious (and potentially damaging,) handling presented by the print roll format, or it may be as MIT Media lab founder Nicholas Negroponte summarizes in his analysis of evolving digital technologies that, ". . . the point is, being digital allows the *process*, not just the product, to be conveyed."[43] Negroponte's statement explains why the origins of the Lander images as artefacts of digital processes, may be more clearly understood, more efficiently accessed, analysed and compared within the digital realm and interactive environment of on-screen devices, online systems, and software systems and applications.

43. Nicholas Negroponte, *Being Digital* (New York: Knopf, 1995), 82.

The Mars Viking Image Products as Part of a Photography Collection in a Museum

To consider why scientific photographs like the Viking Lander image products are important to a photography collection, we must first consider how these might align with the acquisition and larger mission objectives of the institution. The George Eastman House website offers a summary describing the growth of information resources resulting from the continued expansion of the photographic collection: "Purchases of photographs from auctions and dealers, as well as donations from individuals have resulted in a collection that can illustrate and explain, through its objects, almost every aspect of the history and practice of photography, from its inception to the present."[44] An important moment in the history and practice of photography, as well as a significant milestone in the history of human space exploration, are bound together within the Viking Lander images, whether in the physical form of Strip Contact Print rolls or contained as image data on CD-ROM.

From the perspective of the history of photography, the Viking mission serves as an early example of the technological advantages and practical applications possible through digital photography processes. The Viking image products extend the depth of George Eastman House's photography collection because they serve as materials that document the successful adoption of new digital image acquisition technologies. The Lander Imaging Science Team recognized the demands of scale and technological complexity involved in the Viking endeavour in relation to acquiring and processing large volumes of camera data acquired from the remote Martian surface. Levinthal's report acknowledges, "The Viking requirements represented an increased emphasis on flexible, adaptive, and interactive image processing in comparison to previous

---

44. George Eastman House, "FAQ: Photography: Photography Questions," http://www.eastmanhouse.org/Main/museum/faq/photography.php (accessed May 4, 2010).

missions, a new requirement for colour processing, and a considerably greater throughput capacity."[45] To address the issues of flexibility and capacity of the images the mission called for, cameras equipped on the Viking Landers discontinued the long tradition of the camera as an analogue storage device. Rather than directly recording the visual record on physical film-based media, Viking's early digital technology allowed image data to be recorded and relayed in real time, described by Mutch as "generat[ing] data precisely at the rate that it was being transmitted to Earth."[46] Transmission of the image data allowed for more responsive dynamic and "on demand" processing, multiple and simultaneous paths of dissemination to more recipients across diverse locations, and provided flexibility to produce and output a range of image products designed for specific scientific research applications. Most importantly, the Viking Lander digital entities could be preserved by redundancy, given that exact raw image data replicates were and continue to be widely distributed, stored and migrated within NASA's network of archives and research facilities. The concept of redundancy, defined by *The American Heritage Dictionary of the English Language* as "the provision of additional or duplicate systems, equipment, etc., that function in case an operating part or system fails, as in a spacecraft," is a natural carry-over from a principle strategy applied to many of NASA's planetary exploration missions, exemplified by the duplicate systems and spacecraft of Viking I and II.[47]

The Viking images are also an example of the photograph's ability to concisely record a culturally meaningful and historic visual record. Patrick Maynard, adjunct professor in the Film and Philosophy program at York University, is interested in the human perception of visual

---

45. Levinthal et al. "Processing the Viking Lander," 4414.

46. Thomas A. Mutch et al., *The Martian Landscape* (Washington, DC: Scientific and Technical Information Office National Aeronautics and Space Administration, 1978), 7.

47. *The American Heritage Dictionary of the English Language,* 4th ed., s.v. "Redundancy."

records. His description of photographs suits the Viking Lander images: “They are pictures, or, one might say, ‘visual descriptions,’ of their subjects, but they are also visual effects or manifestations of what they depict.”[48] Viking’s images are the first photographic records taken on the surface of Mars, a recorded visual description of a landscape humankind is, thus far, unable to witness in person. The images are an account made possible through the visual effect of photography, a stand-in manifestation for a reality not gathered by the human eye, but captured by remotely operated cameras, described by former Director of NASA’S Langley Research Center, E. M. Cortright, as cameras, “. . . pointed by machines with computer brains, gyroscopic sense, star-seeking eyes, and servomechanism muscles. . .”[49] The visual record resulting from Viking’s camera “machines,” a historic “first” in documenting a landscape located over 70 million kilometres from Earth, aligns well with George Eastman House’s mission, one dedicated to telling the story of photography in history and culture, recognizing photography (and motion pictures) as “. . . media that have changed and continue to change our perception of the world.”[50] The visual evidence provided by Viking has changed the scientific perception of our world by advancing knowledge in areas such as planetology, geology, and biology. Culturally, our perception of the distance between “science fiction” and fact has been reduced by our remote presence on another world, substantiated by the images returned by Viking from Mars. Norman Horowitz, a geneticist whose experiments for the Viking mission were engineered

48 . Patrick Maynard, "The Secular Icon: Photography and the Function of Images," *Journal of Aesthetics & Art Criticism* 42, no. 2 (1983): 156.

49. Edgar M. Cortright, ed., *Exploring Space with a Camera* (Washington, DC: Scientific and Technical Information Division Office of Technology Utilization, National Aeronautics and Space Administration, 1968), ix.

50. George Eastman House, “Mission Statement,” http://www.eastmanhouse.org/Main/museum/mission.php (accessed May 4, 2010).

to detect if life might exist on Mars, links the significance and value of the Viking Landers' photographs in the context of history and culture:

> . . .their photographs are priceless, not only for what they added to our understanding of the Martian environment, but also because these ochre landscapes from the plains of Mars will always be reminders of the historic encounter between myth and technology that took place there in the summer of 1976.[51]

Viking's photographs are a point of historic convergence where the myth of the belief of life on Mars, derived from culturally biased observation, meets with disproving evidence provided by photographic technology, separating myth from fact. The images from the Viking Mission were significant in resolving (for the time being,) the myth of life on Mars, which began with the mistranslation of astronomer Giovanni Virginio Schiaparelli's Mars observation notes made in the 1870s. Man's imagination was ignited by Schiaparelli use of the word "canali" ("grooves" or "channels" in Italian) mistakenly translated as "canals" to describe an area on Mars—suggesting the work of intelligent beings.[52] The myth was perpetuated by science fiction stories including the *Barsoom* series by Edgar Rice Burroughs, *War of the Worlds* by H.G. Wells, and in the biased "scientific" observations of Percival Lowell in his observations of the canals as evidence of civilisation on Mars.[53] The Viking images serve as supporting evidence of the historic myth laid to rest, especially those Lander images which document the trenches dug out of the Martian soil by Viking's mechanical arm for samples used for biological experiments in the unsuccessful search for life on Mars.

---

51. Norman H. Horowitz, *To Utopia and Back: The Search for Life in the Solar System (*New York: W.H. Freeman and Company, 1986), 26.

52. Edward Clinton Ezell and Linda Neuman Ezell, *On Mars: Exploration of the Red Planet, 1958-1978* (Washington, DC: Scientific and Technical Information Branch, National Aeronautics and Space Administration, 1984): 2.

53. *Cosmos*, "Blues for a Red Planet," Episode 5, 1980, Netflix streaming video file http://www.netflix.com/WiPlayer?movieid=70061728&trkid=496817 (accessed March 13, 2010).

We might ask why Viking's scientific image products, as scientific documents and non-art photographic images, should be included as part of the photography collection of George Eastman House. The Mars Viking Images are not intended to be images of artistic visual expression or designed to provoke an aesthetic or emotional response, other than a sense of wonder over the realisation that we are looking at the surface of another planet. Art critic and historian James Elkins, who has written extensively about non-art images, uses the term "informational images," a description directly applicable to the Viking Lander images. Elkins suggests:

> The variety of informational images, and their universal dispersion as opposed to the limited range of art, should give us pause. At the least it may mean that visual expressiveness, eloquence, and complexity are not the proprietary traits of fine art, and in the end it may mean that there are reasons to consider the history of art as a branch of the history of images, whether those images are nominally in science, art, archaeology, or other disciplines.[54]

Elkins's description of informational images allows us to consider that scientific photographs might possess traits we would normally attribute to the realm of art photographs. Scientific photography, with its wider, less limited dispersion, combined with visual attributes often (intentionally or accidently) characteristic of the fine arts, possesses a capacity to influence other cultural disciplines and human history. Scientific photography's cultural potential is acknowledged further by Shirley L. Thomson, former director of the National Gallery of Canada, in her foreword to the 1997 catalogue *Beauty of Another Order: Photography in Science.* Thomson writes, ". . . one writer, witnessing in 1858 the application of photography to science, correctly saw its importance in the continuum of ideas and actions that shape human civilization:

---

54. James Elkins, "Art History and Images that Are Not Art," *The Art Bulletin* 77, no. 4 (December 1995): 553-571.

its role in human history."[55] The photographs of the Viking Lander images illustrate a remote otherworldly location, making an unseen world visible for examination and contemplation by scientists and the public.

While NASA's permanent digital image archive facilities may seem to be the logical location and resource for Viking Lander image products, NASA's image archives are not cultural heritage institutions or museums dedicated to telling the story of photography as is George Eastman House. The Viking image products fit within the history of photography as evidence of a photographic first, both by the location the images depict and by the technologies that were used to obtain the images. Jessica Johnston, Assistant Curator in the Department of Photographs at George Eastman House confirms, "Because it is a first in the history of photography and because it is an example of the evolution of photography, it belongs within the collection at George Eastman House."[56]

Viking Image Products: Objects of Time and Place

In the late 1970s and 1980s, the dissemination of the image rolls to Viking image investigation scientists located at NASA's Regional Planetary Image Facilities in the United States and Europe involved transporting Viking image product materials through available shipping services at a time before image data could be easily distributed through interconnected computer network systems or the Internet.

55. Shirley L. Thomson, foreword to *Beauty of Another Order: Photography in Science,*by Ann Thomas et al., (New Haven: Yale University Press, 1997), 8.

56. Jessica Johnston, conversation with author, May 20, 2010.

The digital entities that make up Viking's Experimental Data Record have been sent and stored across every type of delivery and data storage technology available since their original image capture on Mars in 1976. The image data has been transmitted and carried by UHF radio waves across space and sent as data packets through application, transport, and link layer protocols spanning the history of the Internet. The data has been physically stored and distributed on magnetic tape reels, stored on CD-ROM optical media, imaged on transparent film in rolls, on microfiche, archived as individual 70mm master negatives, and now resides on networked, publicly accessible redundant disk drive arrays in secure server environments. Exact replicates of Viking raw image data are accessible at near instantaneous download speeds through web browser software applications. Despite the technological changes and the vulnerability of magnetic tape storage, the original raw image data of the Viking Experimental Data Record remains intact, accessible and has been preserved through migration and data recovery efforts of the PDS Imaging Node. The Mars Viking digital entities have also been preserved by wide dissemination of replicated data through global accessibility from the online archives at the NASA's National Space Science Data Center and the Planetary Data System.

At the time of their production in 1997, the NASA Viking CD-ROMs were an inexpensive and efficient means of distributing data via a physical product in a standardised format. Though still available for purchase, the CD-ROM set has since given way to the virtually costless and extended technical features offered by broadband high-speed connectivity, offering instant search, browse and download functionality to the Viking image data from NASA's online archives. The Viking CD-ROM set shares similar properties to the image rolls of the Reutershan collection. Though their monetary worth and rarity vary considerably, both represent somewhat obsolete forms of what, at their time of creation, were state of the art technologies. Both image products continue as functional, though somewhat inconvenient forms in terms of handling and accessibility to image data. However, both have relevance within a photography collection as examples of conventional media used to access image assets and provide information transfer to users at the time. The evolving means of access to Viking's digital assets, such as the online digital catalogues available at NASA's image archive web sites, correlates directly to the diversity of user types now accessing Viking's image data. The initial group of research scientists inside NASA's network involved in the mission has broadened out to researchers and scholars interested in the photographic record of space exploration outside of NASA's network, and also extends to the general public now able to access images from various missions through NASA online image archive services.

The Relationship between the Digital Entity and the Analogue Print: Advantages to Holding Both in a Collection

The NASA CD-ROM set, created in 1997 before the PDS Imaging Node began to disseminate images from the Viking Experimental Data Record on the Planetary Image Atlas website, has not been updated or republished. However, the CD-ROM set still serves as an ancillary resource and as a stable preservation copy of exact replicates of the entire Viking Landers' authentic digital record. There may be advantages to ownership of the CD-ROM set, as it serves as a physical storage device rather than only having access to digital entity content through an online resource. For example, there is no assurance that NASA's Planetary Image Atlas website will remain a permanent access point for downloading Viking's original digital entities. Regarding access to critical online content, John M. Budd, Associate Professor at the

University of Missouri's School of Library and Information Sciences, and his colleague Bart Harloe, Librarian at the St. Lawrence Libraries, caution, ". . . access to content can be tenuous, not necessarily because of the content itself, but because of a connection between content and medium. . . .The choice of medium for access does determine the obtainability of the content."[57] Best practice, therefore, may be to acquire digital entities from which photographs are made on physical media storage devices, whenever possible, especially if the acquisition of the storage media is cost effective, as is the case with the Viking CD-ROM set.

Translating the Camera Record Event metadata, as discussed previously, requires access to a set of definitions, which may be found in the supplementary documentation files on each of the PDS Imaging Node CD-ROMs. Details from the Camera Event Record can be used to document the Viking images into collection management databases and digital asset management software systems with intricate detail at the item level, or as a resource to construct label or panel text in supporting of print exhibitions. The CD-ROM set also serves as an image repository from which enlarged print reproductions may be easily and accurately reproduced from the same raw image data transmitted from the Viking Landers in 1976.

Accessing the digital entities on the Viking CD-ROMs, whose entire copyright-free contents may be copied into directories on any hard drive without loss of functionality, provides the flexibility of self-service access and a means to browse and preview images prior to making requests to view, if required, specific prints on the image rolls. This also provides an added benefit of minimising the handling of the more delicate paper substrate of the image roll.

---

57. John M. Budd and Bart M. Harloe, "Collection Development and Scholarly Communication in the Twenty-First Century: From Collection Management to Content Management," in *Collection Management for the Twenty-First Century*, edited by G.E. Gorman and Ruth Miller (Westport, CT: Greenwood Publishing Group, 1997), 20.

The detailed examination conducted in this case study of Viking image products is an example of the investigation process required to properly assess the value and benefit of acquiring both the photographic print and the authentic digital records from which it was made. The metadata held in each Viking Camera Event Record is an example of how critical information related to the origins, resources and processes involved in producing the image is embedded within each digital entity. Viking's metadata, documented by NASA as a Camera Event Record, proved to be a critical resource in understanding the value of and relationship between the Viking digital entities and hard copy image rolls. When asked about the importance of possessing both the print and digital entity from which it was made, Alison Nordström, the Curator of Photographs at George Eastman House responded, "it is useful to collect the primary image source for what it may tell you about the making of the print, the ancillary object."[58]

The evaluation process is not dissimilar to understanding the context of an image in order to understand the subject. In his essay, "The Elephant, the Spaceship and the White Cockatoo," Michael Punt uses the example of Joseph Wright of Derby's 1768 painting *An Experiment On a Bird in the Air Pump*, as a representation of science, technology and entertainment: "To understand the subject matter of this painting," he writes, "it is necessary to consider the cultural (and epistemic) context of the demonstration."[59] Each digital entity or authentic record image object under consideration for acquisition, regardless of its photographic category (e.g. scientific, fine art, journalistic photography) should be investigated on a case-by case-basis, with an objective of understanding and validating its relationship to the corresponding printed image. The acquisition of the Viking Lander image rolls led to an

58. Alison Nordström, conversation with the author, May 20, 2010.

59. Michael Punt, "The Elephant, the Spaceship and the White Cockatoo" in *The Photographic Image in Digital Culture*, ed. Martin Lister (London: Routledge, 1995), 67.

investigation of the availability of the photograph's original source: the easily obtainable and affordable replicated raw image files contained on NASA's Mars Viking EDR image archive CD-ROM set. The decision to acquire the NASA CD-ROMs by George Eastman House demonstrates an understanding of the correlation between the digital entity and the photographic print from which it was made.

Budd and Harloe, though focused on collection management practices within the library environment, offer a view applicable to photography collections and relevant to the Viking image products, advocating the advantages of holding both the printed record and the original digital source. "Some combination of print and electronic formats, given the constraints of content attached to a single medium, becomes a necessity that requires little choice. . . .The overriding concern is a fit of the nature of the content and the use to which it will be put. . . . a physical package may be more effective."[60] The Viking image rolls do have some constraints. They do not represent the entire Viking Experimental Data Record, and they are difficult to handle. However, the physical photographic print format does appeal to our expectations of what a photograph is and how we feel it as a real object in our hands. As Budd and Harloe explain, "The notion of combining the best of print and electronic media implies that no medium, in itself, embodies the capacity for meeting every need, other than the most visceral one for form absent of substance."[61] The image rolls of the Viking image products provide the substance and form of the visual record, while the digital entities and documentation contained on the CD-ROM set present the Viking Mission Experimental Data Record in its entirety.

---

60. John M. Budd and Bart M. Harloe, "Collection Development and Scholarly Communication," 17-18.

61. Ibid., 18.

The Strip Contact Print image rolls, however, do provide the physical means to connect Viking's digital image data to the material objects, the photographic prints. Dr. Fiona Cameron, Senior Research Fellow at the Centre for Cultural Research at the University of Western Sydney, describes the relationship between real objects and their link as signifiers of past. Cameron conveys, "Significantly 'real' objects are deemed to have a historical actuality while acting as a visible sign of the past. They act as fragments of information, having a special place in time and space as survivors of the past ensconced in the museum."[62] The image frames on the Viking Lander image rolls are material evidence, and as photographic prints, a physical reference point of past events, readable fragments of proof on paper documented with comprehensive metadata which accurately details the exact time, place and parameters of each camera event. Viking's photographic image rolls are also a surviving physical record of a manufacturing process specific to a time, place and purpose, one of several image products produced from NASA's first implementation of a new digital acquisition and image production technology.

The Trajectory of the Viking Image Products

Understanding the attributes and origins of the Viking Lander images allows us to consider the historical trajectory of these objects. The path begins with image products derived from Viking's transmitted data, stored and made accessible to NASA scientists at the repositories of NASA's Regional Planetary Image Facilities. Over time, the image products found their way into the museum environment where they have been accepted and re-contextualized as objects of

62. Fiona Cameron, "Beyond the Cult of the Replicant: Museums and Historical Digital Objects – Traditional Concerns, New Discourses," in *Theorizing Digital Cultural Heritage: A Critical Discourse,* eds. Fiona Cameron and Sarah Kenderdine (Cambridge, MA and London: The MIT Press, 2007), 54.

cultural heritage, historic records significant as a photographic first and as the first documentation of an unseen location.

Not only are the Viking image products historical documents, they are documents with a history. They first belonged to a government-funded scientific agency, then were objects for sale in the private market, then objects under private ownership by Christopher Reutershan and finally, became part of a museum collection. Now, as part of the photography collection of George Eastman House, the NASA image products have acquired an institutional identity: “The Reutershan Viking Lander Photograph Collection–Gift of Christopher Reutershan.” In addition to their significance and functional value as scientific objects, and their historic value as a “first” in photography, the Viking image products have become commodified—as a result of their transfer of ownership, they have monetary worth and value as objects of cultural heritage. Their change of ownership has affected how the Viking objects are stored, accessed and used. Their functional value as scientific objects continues outside the museum environment as digital entities accessible through the virtual digital catalogues of NASA’s image archive websites. The Viking image products retain functional value as scientific objects inside the museum but have, as assets re-positioned in George Eastman House, acquired additional functional and cultural values.

The journey of the Viking Lander image rolls not only involves physical relocation, but also a shift in function as they become objects for study within the cultural environment of George Eastman House. Removed from their scientific research origins their function shifts to a wider stage and different purpose, or as Nicholas Negroponte might suggest, “handed off to a body of creative talent, with different values, from a different intellectual subculture."[63] The Viking image objects have now moved into a museum environment, where, as noted by artist, film maker and cinema historian Michael Punt, there is a "convergence of science, technology and entertainment," allowing the Viking images to educate, entertain, or function in both capacities.[64]

Like all photographs the Viking Lander images provide a visual record of memory, history and place. French historian Pierre Nora describes the important relationship between cultural value, history and memory when he writes, "Memory takes root in the concrete, in spaces, gestures, images, and objects; history binds itself strictly to temporal continuities, to progressions and to relations between things."[65] Even if the viewer did not witness the camera events on Mars, their interaction with the Viking images within the collection of a museum re-creates an experience of a historical event—man's first photographs from the surface of another planet.

63. Nicholas Negroponte, *Being Digital*, 82.

64. Michael Punt, "The Elephant, the Spaceship," 54.

65. Pierre Nora, "Between Memory and History: Les Lieux de Mémoire," *Representations* 26 (Spring, 1989): 8, http://www.jstor.org/pss/2928520 (accessed June 10, 2010).

Conclusion

The Viking Lander image rolls are an example of a unique photographic product, a historic record generated from the results of a scientific mission which employed a complex system of spacecraft, camera, data and image processing technologies specific to state-of the-art systems in place at the time. The value of the image rolls is defined by the fact that they collectively contain examples of the first photographs from the surface of another planet. Image roll EDR-1 is of particular importance and value given that the first photograph from Mars, camera event “12A001/000” taken by Viking Lander I, Camera 2, seconds after touchdown, is present on the roll. The image rolls themselves are one example of the many product variations generated from the Viking Experimental Data Record. The combination of image and metadata printed on the image roll presents in material form both a concise visual record and a representation of the technologies involved in the Viking image investigation experiments: acquisition by the Viking facsimile camera, data transmission from the spacecraft to the Deep Space receiving stations, relay to the JPL for image data storage, processing, and final hard and soft copy output as a range of photographic image products. The Viking Lander images retain scientific value as key contributors of evidence used to resolve the issue of the existence of life on Mars, and to advance the planetary sciences—the original objectives of the Viking mission. The entire Mars Viking Lander archive is also a visual and historic record of successful human endeavour and technological achievement.

The first photograph from Mars has significant impact whether it is presented as a small strip contact print from the NASA EDR image roll, or as a LCD display sourced from the original image file from the Viking CD-ROM set or downloaded from the PDS Planetary Image Atlas.

The first photographs captured from the surface of another planet are historic artefacts, authentic images intended foremost for scientific research to enable image investigations by engineers and scientists. The images were painstakingly examined to understand the geological, meteorological and atmospheric conditions of the Martian environment. They were used to evaluate and test the performance, reliability, and control of cameras located over 70 million kilometers away from Earth and to serve as a prototype to conceptualise and build more versatile and more mobile recording instruments for advanced missions to follow such as the Pathfinder Rover and Phoenix Lander missions. Image products from Viking's Experimental Data Record, either as prints on image rolls or as digital entities on CD-ROM are proof of the success of an image capture technology capable of acquiring and transmitting image information from Mars to Earth, reconstructing an image from raw data that at the present time cannot be witnessed directly by the human eye.

By collecting both of these closely tied image objects—the image rolls and the Viking CD-ROM set—each adding informational value to the other, a comprehensive and authentic photographic record archive can be preserved. Additionally, the knowledge of the importance of the Viking image products within the scope of scientific discovery and the history of photography can be shared and made accessible for both research and exhibition purposes by the institution. Gavin McCarthy, director of the Australian Archives Project, defines a larger goal, one relevant to the Viking image products, in his discussion about the importance of preserving the knowledge surrounding digital culture heritage resources. McCarthy describes that the knowledge shared concerning an institution's cultural resources should provide an ". . .implicit understanding of its significance, provenance, and the societal value of the resource and technology to build it."[66] As part of the photography collection of George Eastman House, the Reutershan Collection image rolls and NASA PDS CD-ROMs of the Viking Lander Experimental Data Record can be used to educate and inform viewers about the Mars Viking Mission and the photographic processes and technologies NASA developed to capture, preserve, and organise the authentic digital records of the first photographs from the surface of another planet.

66. Gavin McCarthy, "Finding a Future for Digital Cultural Heritage Resources," in *Theorizing Digital Cultural Heritage: A Critical Discourse,* eds. Fiona Cameron and Sarah Kenderdine (Cambridge, MA and London: The MIT Press, 2007), 256.

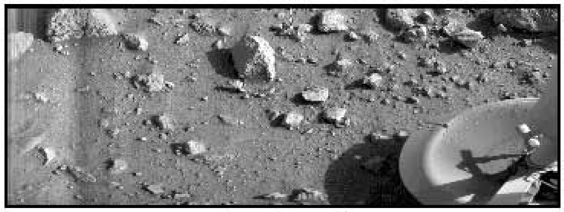
Illustrations

Figure 3. Two examples of NASA / IPL Strip Contact Print image rolls (SCRs) from The Reutershan Viking Lander Photograph Collection at George Eastman House.

Viking Lander Image 12A001.BB1 Page 1 of 1

Viking Lander Image 12A001.BB1

FIRST LANDER 1 IMAGE



PDS Label Parameters

Product Id	12A001-BB1		
Spacecraft Name	VIKING_LANDER_1	Instrument Name	CAMERA_2
Mission Phase Name	PRIMARY MISSION	Target Name	MARS
Start Time	1976-07-20T11:53:15Z	Stop Time	1976-07-20T11:58:22Z
Planet Day Number	0	Local Time	15.79
Start Azimuth	102.50 degrees	Stop Azimuth	160.00 degrees
Center Elevation	-50.00 degrees	Sampling Parameter Interval	0.04 degrees
Observation Type	HIGH RESOLUTION SINGLET	Filter Name	BB1
Gain Number	4	Offset Number	1
Detector Temperature	19.50	Dust Flag	FALSE
Start Rescan Number	0	Total Rescan Number	0
Scan Rate	16000 BPS	Data Path Type	REALTIME UHF LINK
Line Samples	1439	Missing Samples	1
Note	FIRST LANDER 1 IMAGE		

Figure 4. Screen capture of the Quick-Look HTML page interface available on NASA's PDS Viking Lander 1 and 2 CD-ROM set. Note the thumbnail GIF image and navigational graphic objects directly below. The "T" graphic leads to a "Browse Image Directory" or "Top" HTML page to quickly navigate between the entire Viking Lander 1 EDR image archive. The "Arrow Up" graphic navigates the user to an index of all images within the "A" series directory of 255 images. The "Arrow Left" (when present) and "Arrow Right" graphics navigate the user to the previous or next image within the image series. The "Question Mark" graphic on the right leads the user to a "Viking Lander Image Browser Help" HTML page containing comprehensive instructions. The text content below the image lists the Camera Event Record parameters for each image. Each parameter name in blue underlined text is a hyperlink that leads to a data dictionary page which defines and details each parameter term.

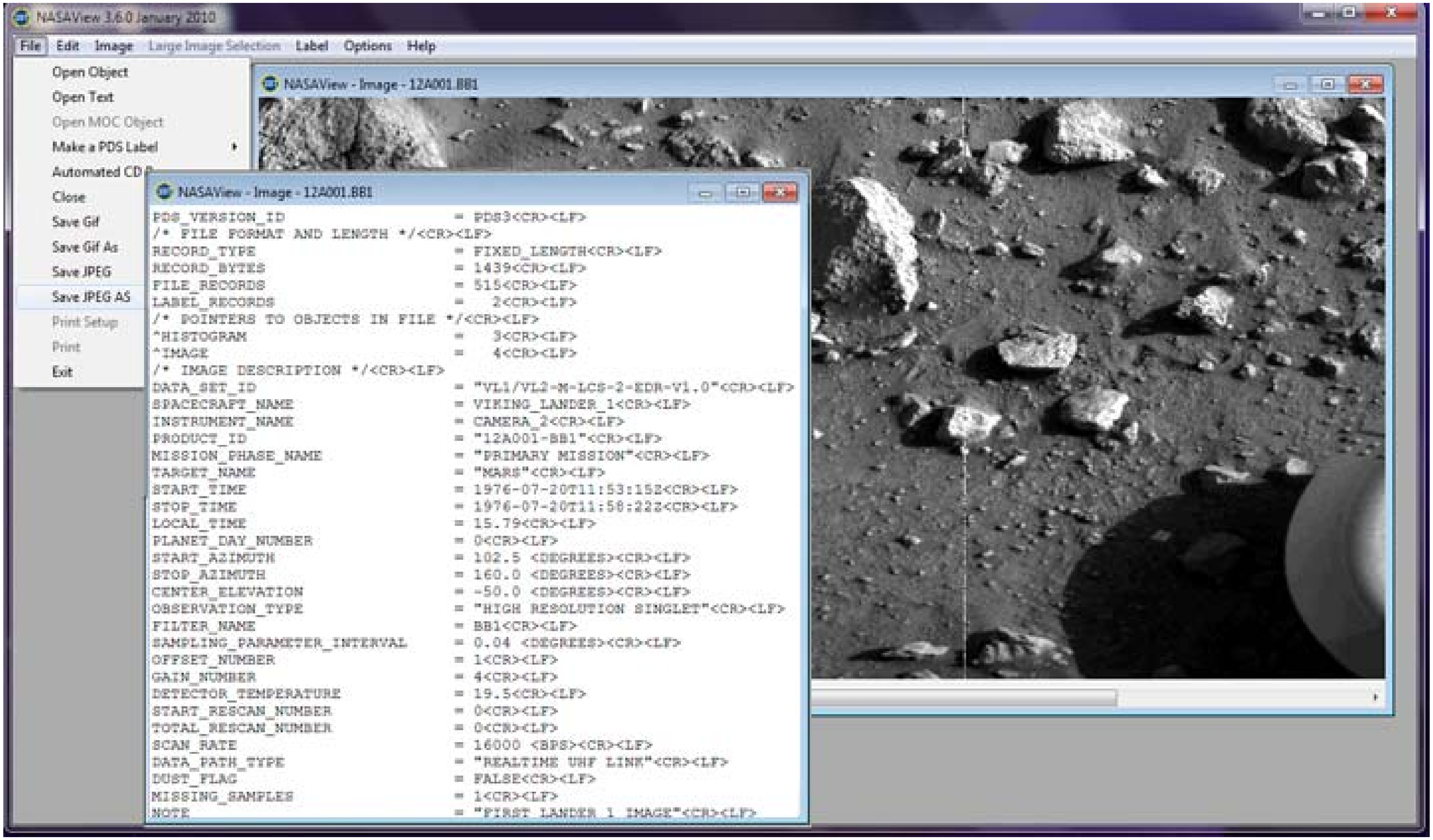


Figure 5– Screen capture of the NASAView application interface. The application allows the user to select a specific image from image data on the CD-ROM set and display a high resolution image in NASA's propriety image PDS format. Amongst other tasks, the user may access and display the Camera Event Record as displayed in the inset above, perform basic image adjustments, view the image histogram, select from a series of colour palettes, and save the image as either a GIF or JPEG image for export to other image software applications.

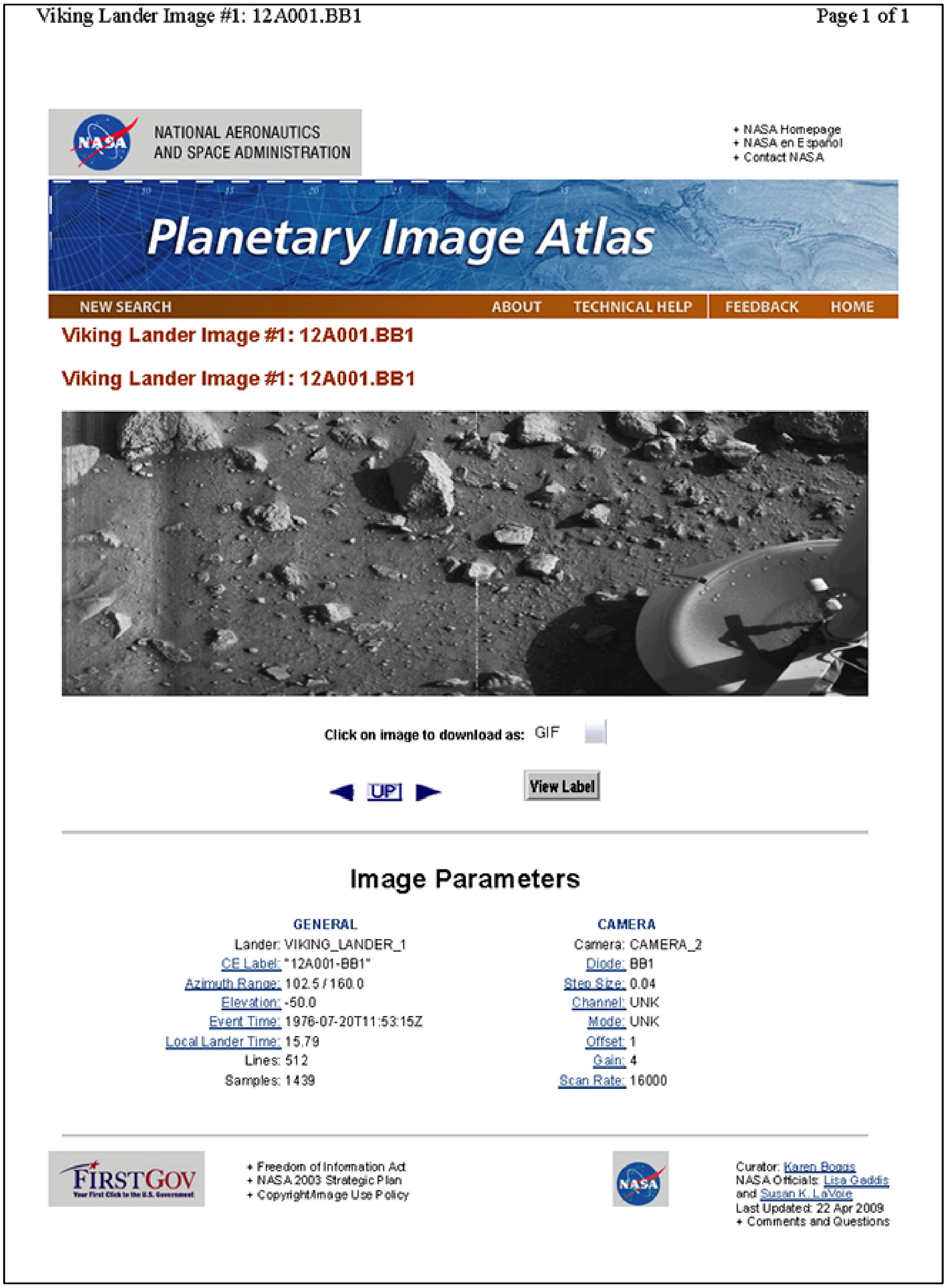


Figure 6. Screen capture of NASA's Planetary Image Atlas website (http://pds-imaging.jpl.nasa.gov/vikingl/vl_images.html). The web page presents the user with selectable options to download the Viking Lander image in either several image file formats including TIFF, GIF and JPEG. Like the Quick-Look CD-ROM browser page, clicking on the underlined blue hyperlinks under "Image Parameters" navigates the user to a Lander Terminolgy HTML page providing a definition for each parameter.

Bibliography

Abelson, Philip H., “Viking 1.” *Science* 193, no. 4255 (August 27, 1976): 723.

Budd, John M., and Bart M. Harloe. “Collection Development and Scholarly Communication in the Twenty-First Century: From Collection Management to Content Management.” In *Collection Management for the Twenty-First Century,* edited by G.E. Gorman and Ruth Miller, 3-28. Westport, CT: Greenwood, 1997.

Cameron, Fiona. “Beyond the Cult of the Replicant: Museums and Historical Digital Objects-Traditional Concerns, New Discourses.” In *Theorizing Digital Cultural Heritage: A Critical Discourse*, edited by Fiona Cameron and Sarah Kenderdine, 49-75. Cambridge, MA and London: The MIT Press, 2007.

Cortright, Edgar M., ed. *Exploring Space with a Camera.* Washington DC: Scientific and Technical Information Division Office of Technology Utilization, National Aeronautics and Space Administration, 1968.

Eastman Kodak Company. *Milestones in Photography / Eastman Kodak Co.* Rochester, NY: Kodak, 1950.

Eliason, Eric M., Susan K. LaVoie, and Laurence A. Soderblom. “The Image Node for the Planetary Data System.” *Planetary and Space Science* 44, no. 1 (January, 1996): 23-32.

Elkins, James. “Art History and Images that Are Not Art.” *The Art Bulletin* 77, no. 4 (December 1995): 553-71.

Ezell, Edward Clinton and Linda Neuman Ezell. *On Mars: Exploration of the Red Planet, 1958-1978.* Washington, DC: Scientific and Technical Information Branch, National Aeronautics and Space Administration, 1984.

Fulchignoni, M., and A. Pichiotti. “Image Processing in Planetology.” *Societa Astromicà Italiana* 57, no. 2 (1986): 123-47.

George Eastman House. “FAQ: Photography: Photography Questions.” http://www.eastmanhouse.org/Main/museum/faq/photography.php (accessed May 4, 2010).

———. Reutershan Collection inventory list. Rochester, NY, 2009.

———. “Mission Statement.” http://www.eastmanhouse.org/Main/museum/mission.php (accessed May 4, 2010).

Godwin, Robert, ed. *Mars: The NASA Mission Reports.* Burlington, Ontario: Apogee Books, 2000.

Guinness, Edward A. “Archive of Viking Lander 1 and 2 EDR Images.” In *Viking Lander 1 EDR Images of Mars – USA_NASA_PDS_VL_0001*, CD-ROM, Version 1,VOLINFO.txt. St. Louis: PDS Geosciences Node Washington University, 1997. This document is also available at: ftp://pdsimage2.wr.usgs.gov/cdroms/viking_lander/vl_0001/document/volinfo.htm.

Guinness, Edward A., Thomas C. Stein, and Jennifer Herron. *Mission to Mars: Viking Lander 1 EDR Images of Mars – USA_NASA_PDS_VL_0001.* CD-ROM, Version 1. St. Louis: PDS Geosciences Node, Washington University, 1997.

Hedstrom, Margaret. “Research Issues in Migration and Long-Term Preservation.” *Archives and Museum Informatics* 11, nos. 3-4 (September, 1997): 287-92.

Horowitz, Norman H. *To Utopia and Back: The Search for Life in the Solar System.* New York: W. H. Freeman, 1986.

F. O. Huck and S. D. Wall, "Image Quality Prediction: An Aid to the Viking Lander Imaging Investigation on Mars," *Applied Optics* 15 (1976): 1748-66.

Image Processing Laboratory. Jet Propulsion Laboratory. *Viking Lander Catalog of EDR Tape Products*, by Susan K. LaVoie. Catalogue report, FTS 792-2057. Pasadena: Jet Propulsion Laboratory, [1982?].

Levinthal, Elliott C., William Green, Kenneth L. Jones and Robert Tucker. "Processing the Viking Lander Camera Data." *Journal of Geophysical Research* 82, no. 28 (September 30, 1977): 4412-20.

Negroponte, Nicholas. *Being Digital.* New York: Knopf, 1995.

Maynard, Patrick. "The Secular Icon: Photography and the Function of Images." *Journal of Aesthetics & Art Criticism* 42, no. 2 (1983): 155-69.

McCarthy, Gavin. "Finding a Future for Digital Cultural Heritage Resources." In *Theorizing Digital Cultural Heritage: A Critical Discourse,* edited by Fiona Cameron and Sarah Kenderdine, 245-60. Cambridge, MA and London: The MIT Press, 2007.

Mutch, Thomas A.,Viking Lander Imaging Team, United States, National Aeronautics and Space Administration and Technical Information Office. *The Martian Landscape.* Washington, DC: Scientific and Technical Information Office National Aeronautics and Space Administration, 1978.

NASA. "NASA-NSSDC-Data Collection – Details: Viking 2 Lander Raw Image EDRs on CD-ROM (PDS)." National Space Data Center. http://nssdc.gsfc.nasa.gov/nmc/datasetDisplay.do?id=PSPG-00184 (accessed June 24, 2010).

———. "NASA-NSSDC-Experiment-Details: Lander Imaging." National Space Science Data Center. http://nssdc.gsfc.nasa.gov/nmc/experimentDisplay.do?id=1975-075C-06 (accessed June 24, 2010).

———. "NSSCD CD-ROM Catalogue – Lander." National Space Science Data Center.

http://nssdc.gsfc.nasa.gov/cd-rom/web_store.cgi?category=lander (accessed May 11, 2010).

———. Scientific and Technical Information Branch. *Conclusion of Viking Lander Imaging Investigation: Picture Catalog of Experiment Data Record*, by Stephen D. Wall and Teresa C. Ashmore. NASA Reference Publication P-1137. Washington, DC, 1985. http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19850012789_1985012789.pdf (accessed February 18, 2010).

———. Scientific and Technical Information Office. *Viking Lander Atlas of Mars*, by Sidney Liebes, Jr. NASA Contractor Report 3568. Washington, 1982. http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19830005765_1983005765.pdf (accessed June 9, 2010).

Nora, Pierre. "Between Memory and History: Les Lieux de Mémoire." *Representations* 26 (Spring, 1989): 7-24.

Punt, Michael. "The Elephant, the Spaceship and the White Cockatoo." In *The Photographic Image in Digital Culture*, edited by Martin Lister, 51-74. London: Routledge, 1995.

Thomas, Ann, Marta Braun, Mimi Cazort, Martin Kemp, John P. McElhone, and Larry J. Schaaf. *Beauty of Another Order: Photography in Science.* New Haven: Yale University Press, 1997.

United States National Aeronautics and Space Administration. *NASA Facts: Viking Mission to Mars.* NASA Facts NF-76. Pasadena, CA: Jet Propulsion Laboratory, California Institute of Technology, 1988.