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The Mariner Mars 1969 Image Bundle Archive Overview

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1.0 Introduction

The Mariner Mars 1969 Mission (NASA SP, 1969 and MM69 Handbook, 1969) sent two spacecraft, Mariner 6 and Mariner 7, to Mars arriving 30 July and 04 August 1969, respectively. Each spacecraft carried a wide angle and narrow angle camera, mounted to two degree-of-freedom scan platforms to point the cameras at Mars during encounter. Each spacecraft implemented Far Encounter and Near Encounter sequences. Mariner 6 took 49 Far Encounter images and 25 Near Encounter images while Mariner 7 took 94 Far Encounter images and 31 Near Encounter images (Collins, 1971, Dunne, *et. al.*, 1971, Leighton, *et. al.*, 1969, Leighton and Murray, 1971, Smith, 1970, and Rindfleisch, *et. al.*, 1971).

These images and associated NAIF SPICE kernels have now been restored / created under the NASA Planetary Data Archiving, Restoration, and Tools Program within the Planetary Science Division of the Science Missions Directorate. The first phase activity (Duxbury, 2017), completed in 2017, focused on the Far Encounter images (http://pds-geosciences.wustl.edu/missions/mariner/duxbury_mariner69.htm) while the second phase activity, ending in 2020, focused on the Near Encounter images. The contents of the Mariner Mars 1969 Encounter Image Bundle Archive are shown in Figure 1.

2.0 Mariner Mars 1969 Image Bundle Archive

The Mariner Mars 1969 Image Bundle Archive has the following five data collections:

1. Document Collection
2. Data Table Collection
    a. Far Encounter
    b. Near Encounter
3. Data Mars Far Collection
    a. Mariner 6
    b. Mariner 7
4. Data Mars Near Collection
    a. Mariner 6
    b. Mariner 7
5. SPICE Kernel Collection

The contents of these PDS4 and NAIF compliant encounter collections are described in the following subsections. All archival files listed in the following sections also have detached PDS4 .xml label files.

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Figure 1. The Mariner Mars 1969 Image Bundle Archive

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2.1 Document Collection

Supporting documentation in the bundle archive includes:

- This document describing the content of the entire Far and Near Encounter archive collection (*mr69_image_bundle_overview.pdf*);
- The source of each Experiment Data Record image archived plus a listing of over 500 other versions (*mr69_image_source.pdf*) that were produced by the Mariner Mars 1969 mission that were not included within the scope of the PDART project;
- The thumbnail images of all Mariner 6 and 7 Far and Near Encounter images (*mr69_thumbnail_images.pdf*)
- The derivations of the SPICE kernels
    - Far Encounter: *mr69_camera_model.pdf* and *mr69_ck_and_fk.pdf;*
    - Near Encounter: *mr69_ne_camera_model.pdf; mr69_ne_ck_and_fk.pdf;* and
    - Far and Near Encounter: *mr69_sclk.pdf and mr69_bsp.pdf*;

and supporting publications that are listed in *mr69_references.txt*:

- A Mariner-Mars 1969 document: A Preliminary Report, 1969 (*mr69_prelim_report.pdf*);
- The first-look science derived from the images (Leighton, et.al., 1969, Leighton and Murray, 1971);
- Camera and digital image descriptions (Danielson and Montgomery, 1971 and Rindfleisch, et. al., 1971);
- Phobos: Preliminary Results from Mariner 7 (Smith, 1970);
- Mission and spacecraft descriptions (The Mariner Mars 1969 Handbook, 1969); and
- Conference abstracts/presentations describing this PDART task.

2.2 Data Table Collection

2.2.1 Far Encounter Data Table Collection

Three type of catalogs were produced: 1) a star catalog (*mr69_star_catalog.tab*) with detached label (*mr69_star_catalog.xml*) that contains information about stars in the vicinity of Mars (Figure 2) as seen from the spacecraft during Mariner 6 and 7 Far Encounter sequences; 2) parameter values for the camera vidicon geometric models, *mr69_camera_distortion_catalog.tab*, with a detached label, *mr69_camera_distortion_catalog.xml*; and 3) a searchable catalog *mr69_image_catalog.tab*, with detached label, *mr69_image_catalog.xml*, to allow a user to determine which images and image locations contain areas of interest.

The star catalog (Figure 2) contains all stars brighter than 8th visual magnitude that were within 5 degrees of the direction to Mars during the Far Encounter sequences. The catalog was derived from the Tyco II catalog in EME J2000 at an epoch of 01 August 1969.

The Mariner Mars 1969 cameras used vidicon tubes, which had significant geometric distortions that changed from image to image. Therefore, the table

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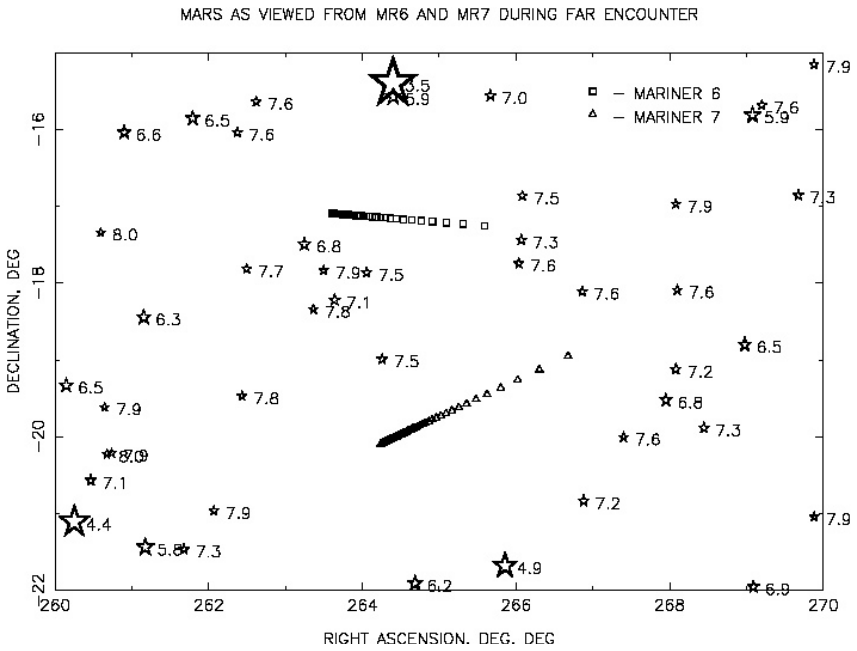

Figure 2. Star background during Mars Far Encounter mission phases

mr69_camera_distortion.tab with label *mr69_camera_distortion.xml* contains the vidicon geometric parameter values for Mariner 6 and 7, Narrow Angle camera, Far Encounter images needed for geometric computations. Average vidicon geometric parameter values are included in the SPICE Instrument kernels *mr6_na_tcd_v10.ti* and *mr7_na_tcd_v10.ti*. The camera optical parameters were constant across all images and are also included in the SPICE Instrument kernels *mr6_na_tcd_v10.ti* and *mr7_na_tcd_v10.ti*. For those performing precision geometric computations, the vidicon geometric parameter values included in *mr69_camera_distortion_catalog.tab* should be used in place of the average values included in *mr6_na_tcd_v10.ti* and *mr7_na_tcd_v10.ti.*

With the creation of SPICE kernels associated with the images, a searchable catalog was produced (mr69_image_catalog.tab with a detached xml label) for the images allowing users to locate areas of interest across all images from both spacecraft and all four cameras. Since Mars only partially fills the camera fields-of-view during Far Encounter making the image corners not on the Mars surface, Mars was divided into the 30 Mars Quadrangles (Figure 3) and each quadrangle divided into 4 sub-quadrangles to provide 120 searchable Mars location metadata. The viewing and lighting conditions for each of the 120 Mars sub-quadrangles, ESA Beagle 2 and all NASA landers to date, through MSL, were computed and stored in the searchable table. The searchable quantities include

- Mission, Spacecraft and Image ID (PICNO)
- Filter position and shutter direction;
- Image time (UTC);
- Time from Mars closest approach (DAYS:T:HOURS:MINUTES:SECONDS)
- The Mars sub-quadrangle name and number (1-30: a, b, c and d) and 8 landers (VL-1, VL-2, MPF, MPL, Beagle 2, MER-A, MER-B, and MSL);

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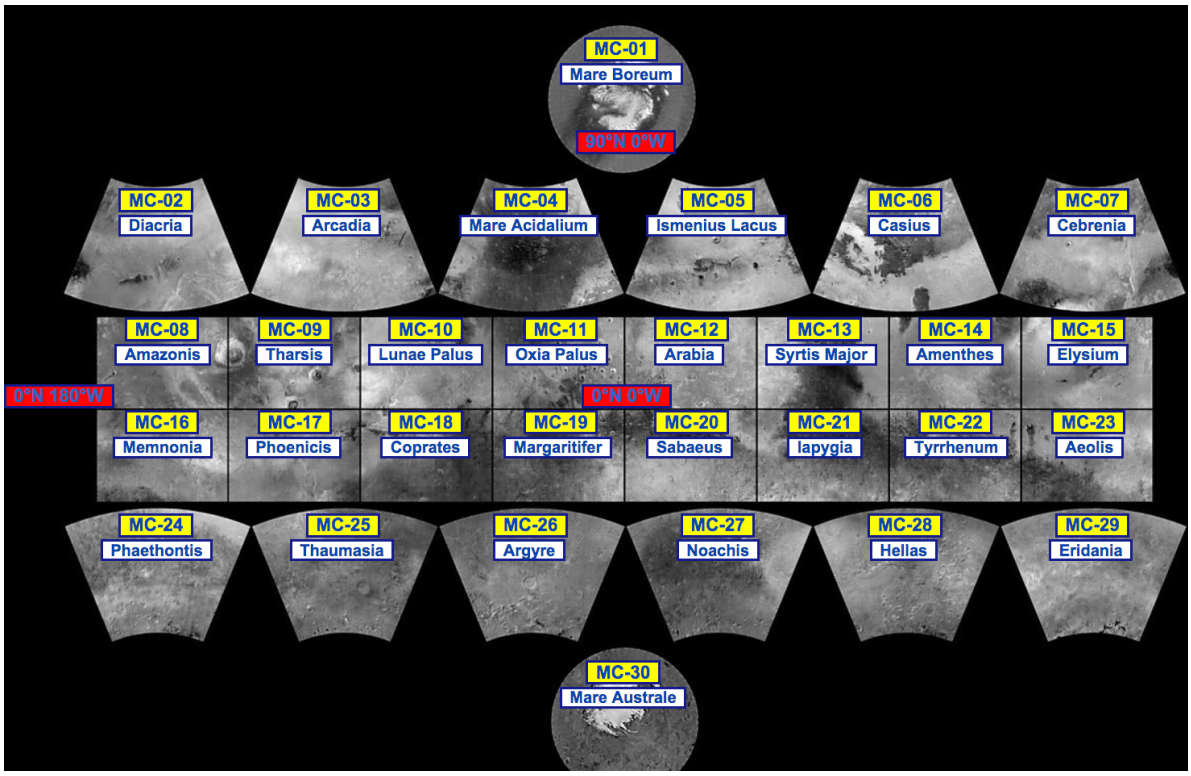

Figure 3. Mars Quadrangles taken from https://en.wikipedia.org/wiki/List_of_quadrangles_on_Mars

- Image PICNO and image location (sample and line) of sub-quadrangles and landers/rovers;
- The viewing / lighting angles of emission, incidence, phase and solar distance of the sub-quadrangles and landers/rovers;
- The scaling parameters of slant range and km/pixel at the quadrangle centers and lander/rover locations;
- The Mars season, L_s;
- The sub-spacecraft and sub-solar points on Mars of latitude, longitude and range;

All angles are Areocentric and have units of degrees and distances are expressed in km. Since there are 4 sub-quads for each of the 30 Mars-quads, up to 4 lines in the catalog may exist for a Mars quad relative to its a, b, c and d sub-quads.

2.2.2 Near Encounter Data Table Collection

Three types of catalogs were produced for Near Encounter, each with detached *.xml* label records:
1) parameter values for the camera vidicon geometric models, *mr69_ne_camera_vidicon_model _catalog.tab* (*mr69_ne_camera_model.pdf,* Duxbury, 2019);

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2) searchable catalogs, *mr69_ne__image_catalog.tab* and *mr69_ne_feature _catalog.tab*, to allow a user to determine which images and image locations contain viewing, lighting and areas of interest; and
3) the measured image locations of all observed reseaux in *mr69_ne_reseau_catalog.tab*.

The Mariner Mars 1969 cameras used vidicon tubes, which had significant geometric distortions, that changed from image to image. Therefore, the table *mr69_ne_camera_vidicon_model_catalog.tab* contains the vidicon geometric parameter values for all Mariner 6 and 7 Narrow and Wide Angle camera Near Encounter images needed for geometric computations. Average vidicon geometric parameter values are included in the SPICE Instrument kernels *mr6_ne_na_tcd_v10.ti*, *mr6_ne_wa_tcd_v10.ti, mr7_ne_na_tcd_v10.ti* and *mr7_ne_wa_tcd_v10.ti*. The camera optical parameters were constant across all images for Far and Near Encounter and are also included in these SPICE Instrument kernels. For those performing precision geometric computations, the vidicon geometric parameter values for each image should be used instead of the average values.

With the creation of SPICE kernels associated with the images, searchable catalogs were produced (*mr69_ne_image_catalog.tab* and *mr69_ne_feature_catalog.tab*) for the images allowing users to locate viewing, lighting and areas of interest across all images from both spacecraft and all four cameras. The contents of the Far and Near Encounter Image Catalogs are the same. An additional catalog, *mr69_ne_feature_catalog.tab*, included viewing and lighting metadata on the Mars sub-quadrangle name and number (1-30) and 9 landers (VL-1, VL-2, MPF, MPL, Beagle 2, MER-A, MER-B, MSL and InSight). All angles are Areocentric and have units of degrees and distances are expressed in km.

2.3 Data Mars Far Collection– Mariner 6 and 7

This collection was derived from the raw Level-2 Experiment Data Records that were full frame 946 x 704 x 8 bits/pixel images with no distortion corrections and the reseaux grids were not removed from the images. These types of images were not available for all of the Near Encounter mission phase images. Therefore, the set of images that existed for all Near Encounter images, distortion corrected and resampled at 1,000 x 772 x 8 bit/pixel, was chosen to create the image collection for Near Encounter. These images required a different camera model for near encounter that was different from the Far Encounter camera model as described in *mr69_ne_camera_model.pdf*, Duxbury, 2019.

An image cube was produced for each of the Far Encounter images having five planes and each plane having 946 samples per line, 704 lines and 8 bits/pixel where:

1. Plane 1 contains the original level-2 Experiment Data Record (EDR) image;
2. Plane 2 contains Plane 1 but with all known / found artifacts of reseaux, missing lines, blemishes and noise spikes removed;
3. Plane 3 contains a high-pass filtered version of Plane 2 to enhance Mars surface features and point sources such as Phobos, Deimos and stars. A latitude grid at

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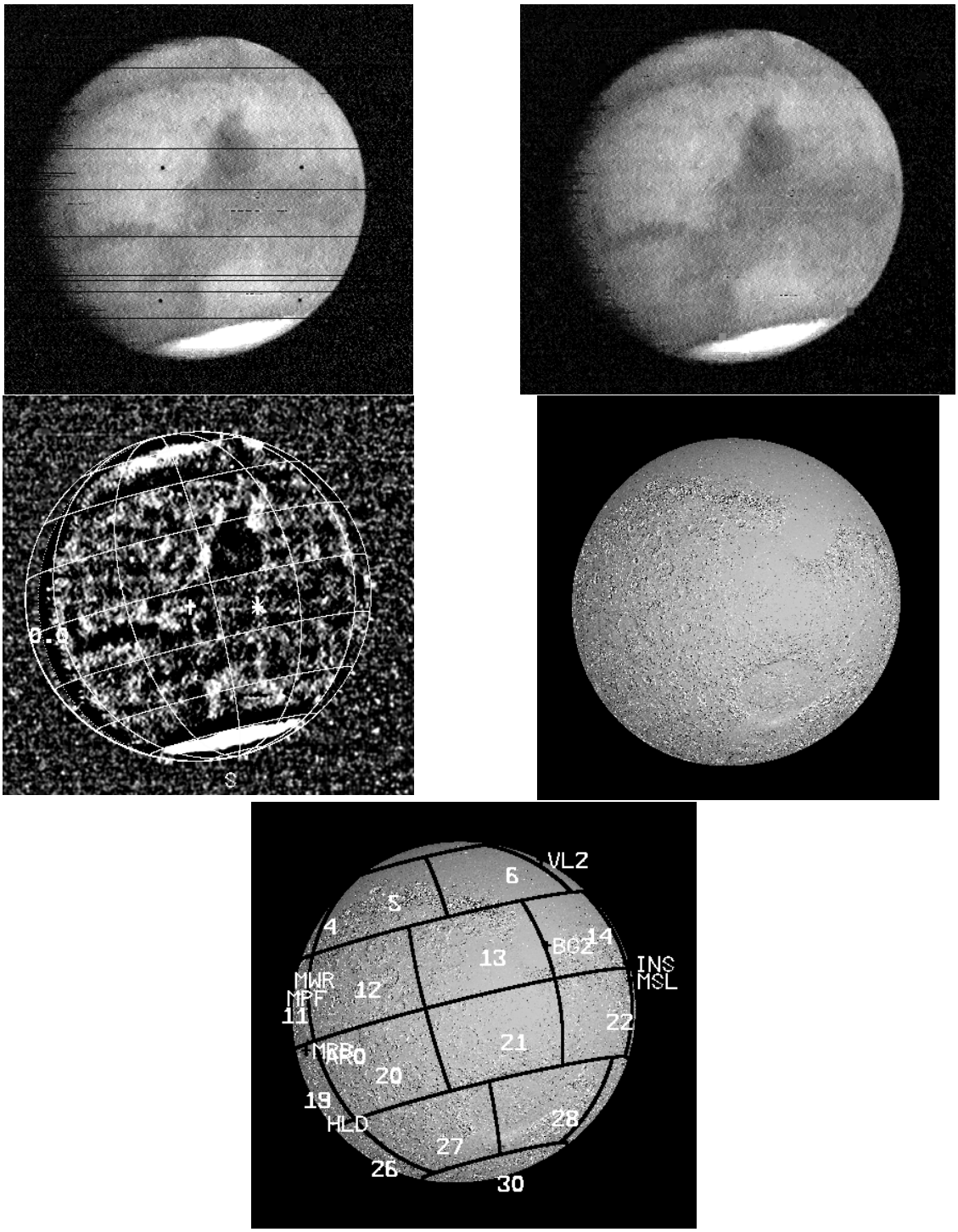

Figure 4. Five-band restored image for 7f63: upper left – raw EDR; upper right – cleaned EDR; middle left – high pass filtered with limb/terminator/latitude /longitude/Phobos/Deimos/star overlays; middle right – simulated image using illuminated MOLA DTM; lower – MOLA DIM with Mars quad and lander locations

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every 20 deg, a longitude grid at every 45 deg, the prime meridian or 180 deg longitude meridian, the south pole (S) and the predicted locations of Phobos, Deimos and stars were drawn as overlays within the 8 bit/pixel image. The limb / terminator overlays have DN = 253, the sub-spacecraft (+) and sub-solar (*) points have DN = 254 and the Phobos / Deimos / star overlays have DN=255;

4. Plane 4 contains a simulated Mars image derived by illuminating the global Mars Orbiter Laser Altimeter (MOLA) global digital terrain model (DTM) to better show what surface features were imaged; and
5. Plane 5 contains the simulated image in plane 4 with Mars quadrangle boundaries and lander locations included as overlays within the 8 bit/pixel image. The overlay image information have DN = 0 or 255.

An example of a 5-band restored image is shown in Figure 4 for Mariner 7 Far Encounter image # 63 (7f63).

2.3.1 Mariner 6

The image cube file naming convention used for Mariner 6 was

xyzz.img where
x = 6 for Mariner 6;
y = f for Far Encounter;
zz = 0 – 49 to indicate the image number within the mission phase.

Each image cube has a detached label record 6fZZ.xml.

2.3.2 Mariner 7

The image cube file naming convention used was

xyzz.img where
x = 7 for Mariner 7;
y = f for Far Encounter;
zz = 0 – 92 to indicate the image number within the mission phase.

Each image cube has a detached label record 7nZZ.xml.

2.4 Data Mars Near Collection

For the Near Encounter images, up to 6 versions existed on the original PDS-supplied, CD-ROM (*mr69_image_source.pdf*, Duxbury, 2016) from which the restored bundle archive was created. Figure 5 shows all 6 versions of image 6n21 that included Composite Analog Video (CAV), Digital Video (DV), Distortion Corrected (DC) and Raw (RW) versions, having

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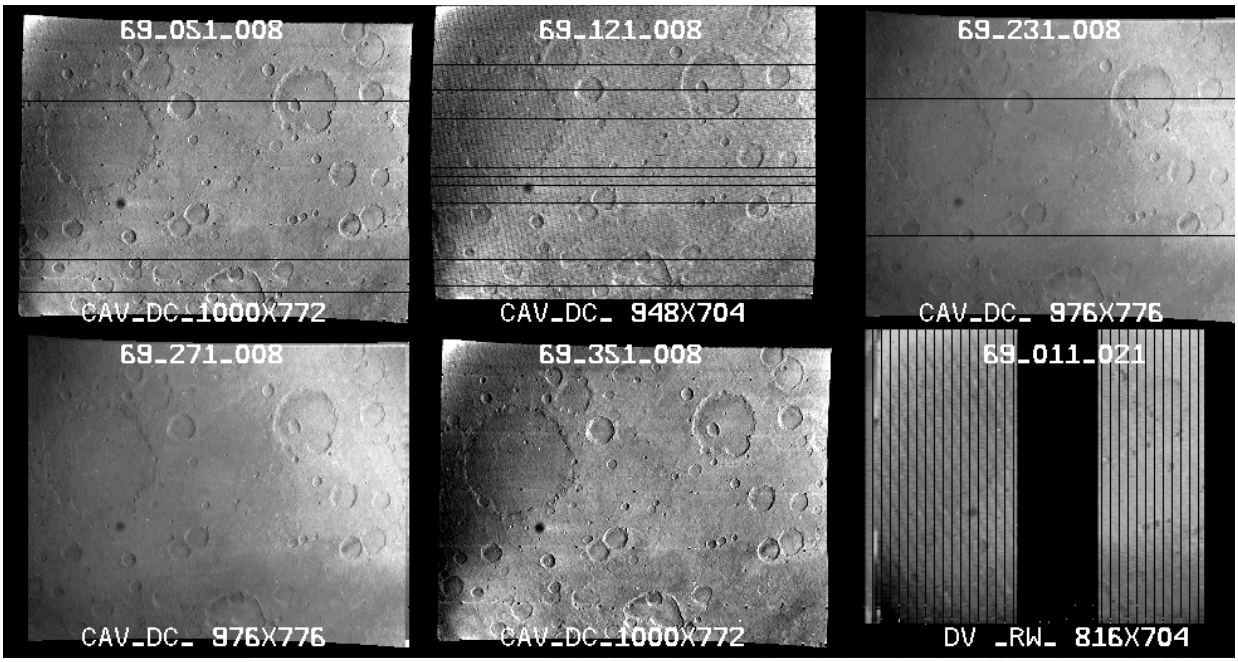

Figure 5. Six versions of 6n21, archived as 6n21_versions_summary.img

sizes of 1000 x 772, 948 x 704, 976 x 776 and 816 x 704 samples / lines with reseaux in and reseaux removed, and with missing lines and filled missing lines. The upper left image version of each Near Encounter image contained the reseaux grid and was used to measure the reseaux locations (*mr69_reseaux_catalog.tab*) to develop the camera vidicon models for each image (*mr69_ne_camera_model.pdf*). The lower – center version of each Near Encounter image was used as the original image in the restored bundle archive.

One major artifact in the original images was the residual image from the previous image. The vidicons were readout a few times to erase the current image prior to taking the next image. However, a residual of the previous image was still on the vidicon and added to the next image. The Mariner Mars 1969 project made attempts to remove this residual image on the ground with limited success. There is no visible residual image in the image versions in Figure 5 where the Mars surface fills the image. However, any of the images that contained the limb have significant residual image. Herkenhoff, 1988, looked at this problem in detail for the Mariner 9 vidicon images of Mars that also had residual images.

For the restored bundle archive, an image cube was produced for each of the Near Encounter images having five planes and each plane having 1000 samples per line, 772 lines and 8 bits/pixel where:

1. Plane 1 contains the Composite Analog Video (CAV), Distortion Corrected (DC) image (Figure 7 upper left);
2. Plane 2 contains Plane 1 but with all known / uncorrected / found artifacts of reseaux, missing lines, blemishes and noise spikes removed (Figure 7 upper right);

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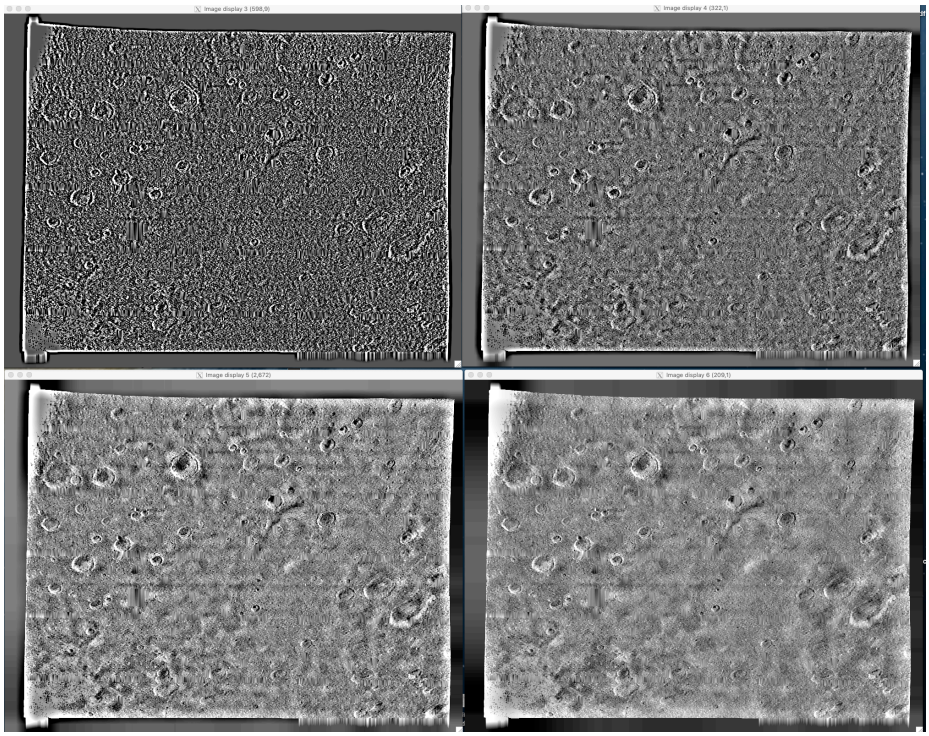

Figure 6. High pass filtered version of 6N11 using filter sizes of 15 x 11, 31x21, 51x41 and 101x81 to enhance surface features obscured by dust

3. Plane 3 contains a high-pass filtered version of Plane 2 to enhance Mars surface features, as there was significant dust in the Martian atmosphere during the Near Encounter mission phases (Figure 7 middle left). Different sizes of high-pass filters were used to determine the size that minimized ringing while enhanced the features. Figure 6 shows image 6n11 after high pass filters of 15 x 11, 31 x 21, 51 x 41 and 101x81 samples/lines were applied. The smallest filter (upper-left) exaggerated high frequency features and noise while the largest filter (lower-right), yielded something very similar to the original image. The 31 x 21 size high pass filter (upper-right) was chosen for all images to enhance features by removing the low frequency brightness variations across the images.

4. Plane 4 contains a simulated Mars image derived by illuminating the Mars Orbiter Laser Altimeter (MOLA) global digital terrain model (DTM, Smith, *et. al*. 2001 and Neumann, *et. al*., 2001) to better show what surface features were imaged (Figure 7 middle right); and
5. Plane 5 contains Plane 2 with latitude/longitude grids at every 5 deg for Wide Angle images and at every 0.5 deg for the Narrow Angle images, the centers of the 30 Mars quadrangles and lander/rover locations included as overlays within the 8 bit/pixel image (Figure 7 bottom). The overlay image information have DN = 0 or 255.

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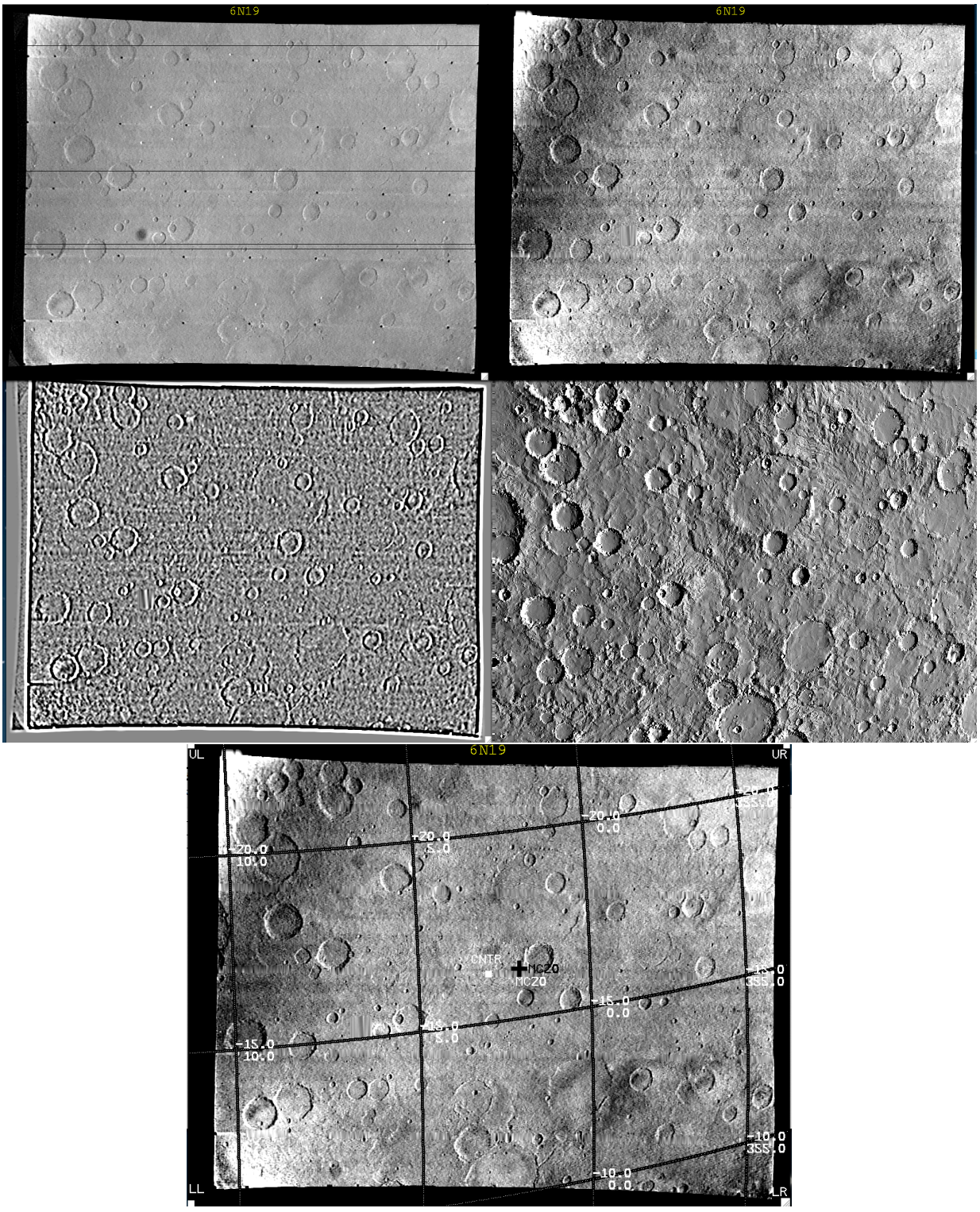

Figure 7. The 5-Plane restored bundle archive image for 6N19. Plane 1 (upper left) original image; Plane 2 (upper right) artifacts removed; Plane 3 (middle left) filtered; Plane 4 (middle right) MOLA-derived DIM; Plane 5 (bottom) gridded.

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2.4.1 Mariner 6

The restored bundle archival image cube file naming convention used was 6nyy.img where 6 for Mariner 6, n for Near Encounter and yy = 01 – 25 to indicate the image number within the Near Encounter mission phases. Each image cube has a detached label record. The various versions of each image to select Plane 1 from are included in the bundle archive as 6nyy_versions_summary.img with detached labels 6nyy_versions_summary.xml.

2.4.2 Mariner 7

The restored bundle archival image cube file naming convention used was 7nyy.img where 7 is for Mariner 7, n for Near Encounter and yy = 01 – 32 to indicate the image number within the Near Encounter mission phases. Each image cube has a detached label record 7nyy.xml, defined in *mr69_ne_image_catalog.xml*. The various versions of each image to select Plane 1 from are included in the bundle archive as 7nyy_versions_summary.img with detached labels 7nyy_versions_summary.xml.

2.5 SPICE Kernel Collection

The NAIF SPICE system (Acton, 1996 and Acton, et. al., 2017) did not exist in 1969 and therefore SPICE kernels were not produced for the Mariner Mars 1969 Mission or its spacecraft systems and subsystems, cameras and images, making any higher-level data processing difficult or impossible to perform. A unique aspect of this PDART task was to create the necessary NAIF SPICE kernels so that the full capability of the NAIF Toolkit and image processing systems such as the JPL MIPL VICAR, the USGS ISIS, and third party software such as IDL, MATLAB, etc. can be applied to these images, making them tremendously more useable by the planetary science community. A complete set of SPICE kernels was created that are listed in the SPICE meta-kernels "*mariner69_v03.tm*" (for Far Encounter) and "*mariner69_ne_v01.tm*" (for Near Encounter) and *collection_spice_kernels_inventory.csv*. These make using the Mariner 69 kernels collection much easier. The following SPICE kernels can be loaded ("furnished") into a user's program, preferably using the Far and Near encounter meta-kernels, to take advantage of the NAIF Toolkit software system:

2.5.1 *Trajectory SP Kernels (mr69_bsp.pdf, Duxbury and Jacobson, 2017)*:
mr6_690721_690810_ssd_v10.bsp
mr7_690726_690815_ssd_v10.bsp
covering the entire Far and Near encounter time periods

2.5.2 Instrument I Kernels *(mr69_camera_model.pdf, Duxbury, 2017* and *mr69_ne_camera_model.pdf, Duxbury, 2019). For Far Encounter:*
mr6_na_tcd_v10.ti
mr7_na_tcd_v10.ti

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For Near Encounter:

mr6_na_ne_tcd_v10.ti
mr6_wa_ne_tcd_v10.ti
mr7_na_ne_tcd_v10.ti
mr7_wa_ne_tcd_v10.ti

where

"*na"* is for the Narrow Angle TV camera
"*wa"* is for the Wide Angle TV camera
"ne" is for Near Encounter

Note that the Narrow Angle TV camera I Kernels for Far and Near Encounters contain different camera parameter data for this same camera and must not be loaded together.

2.5.3 *Spacecraft Attitude/Camera Pointing C Kernels (mr69_ck_and_fk.pdf, Duxbury and Semenov, 2017, mr69_ne_ck_and_fk.pdf, Duxbury and Semenov, 2019). For Far Encounter:*

mr6_sc_690729_690730_tcd_v10.bc
mr7_sc_690802_690804_tcd_v10.bc
mr6_na_690729_690730_tcd_v10.bc
mr7_na_690802_690804_tcd_v10.bc

For Near Encounter:

mr6_sc_690731_690731_tcd_v10.bc
mr7_sc_690805_690805_tcd_v10.bc
mr6_na_690731_690731_tcd_v10.bc
mr7_na_690805_690805_tcd_v10.bc
mr6_wa_690731_690731_tcd_v10.bc
mr7_wa_690805_690805_tcd_v10.bc

where "sc" is for the spacecraft-fixed **ABC** axes celestial Sun-Canopus orientation in EME J2000, "na" is for the Narrow Angle camera, "wa" is for the Wide Angle camera and the time span given in YRMNDY_YRMNDY. The pointing data were derived by changing the computed camera pointing to register simulated MOLA digital image model (DIM) images in the blue channel, with the actual images in the red and green channels (Figure 8).

2.5.4 *Frames Kernels (mr69_ne_ck_and_fk.pdf, Duxbury and Semenov, 2019) for both Far and Near Encounter:*

mr6_v10.tf
mr7_v10.tf

2.5.5 *Spacecraft Clock Kernels (mr69_sclk.pdf, Duxbury and Semenov, 2017b) for both Far and Near Encounter:*

mr6_fict_v10.tsc
mr7_fict_v10.tsc

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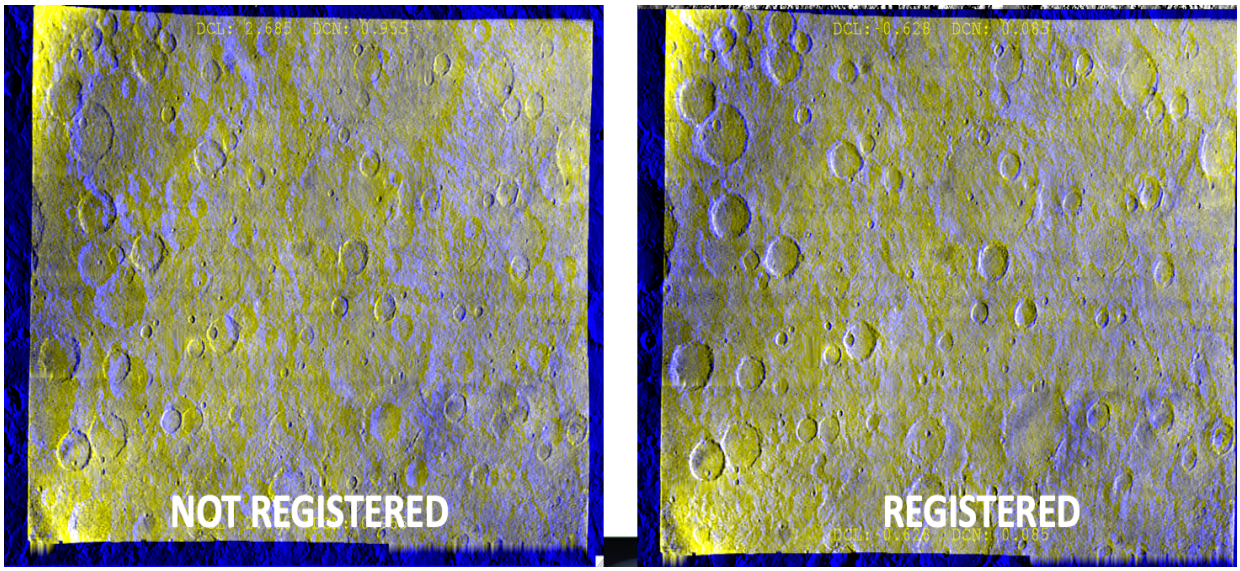

Figure 8. Using NAIF SPICE kernels, all images were simulated by illuminating the global MOLA DTM and map projecting the resultant DIM into image coordinates. Incorrect camera pointing angles result in a mis-registration of the actual and DIM images (left). Changing the camera pointing angles changes the map projection to yield a registration (right) allowing the mapping between Mars-fixed and image coordinates at the pixel level.

2.5.6 *SPICE Generic Kernels (Acton, et. al., 2017) for both Far and Near Encounter::*

naif0012.tls
pck00010.tpc
de432s_mar097s_690101_710101.bsp

2.5.6 *SPICE Meta-kernels (Acton, et. al., 2017). For Far Encounter:*

mariner69_v01.tm
mariner69_v03.tm
mariner69_v03.tm (supersedes two previous versions)

For Near Encounter:

mariner69_ne_v01.tm

Note that because the Narrow Angle TV camera I Kernels for Far and Near Encounters listed in the corresponding meta-kernels contain different camera parameter data for this same camera, the Far and Near Encounter meta-kernels must not be loaded together.

Derivations and contents of these SPICE kernels are listed in the references.

3.0 ACKNOWLEDGEMENTS

This effort was funded under the NASA Planetary Data Archiving, Restoration, and Tools Program (PDART – Dr. Sarah Noble, Lead Discipline Scientist) within the Planetary

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Science Division (PSD) of the Science Missions Directorate (SMD). This restoration effort would not have been possible without the initial support of Susan LaVoie and Amy Culver, PDS Imaging Node at the Jet Propulsion Laboratory, in locating and providing the CD-ROM containing the images in old, non PDS-complaint formats. PC-based software developed by Piotr A. Masek was used to extract over 600 images from the CD-ROM and saved as BitMap Picture (.bmp) files as input to the restoration. Dr. Boris Zhukov, Russian Academy of Sciences Space Research Institute, provided the facility to extract the images from the original PDS-provided CD-ROM as .bmp files. Ms. Susan Slavney and Jennifer Ward, PDS Geosciences Node at the Washington University, provided verbal and written direction, excellent examples and details for files / formats / contents as well as produced some of the archive files directly. Charles Acton and Boris Semenov, NAIF SPICE Node at the Jet Propulsion Laboratory, provided excellent examples and details for files / formats / contents and produced some of the archive files directly. The publication by Campbell (1970) contained the time tags, spacecraft positions and approximate pointings of all images that were necessary to create the NAIF SPICE Kernels. Dr. Robert Jacobson, Jet Propulsion Laboratory, produced the NAIF SPICE trajectory kernels (.bsp) from the Mariner 6 and 7 spacecraft positions. Finally, Dr. David Smith, Massachusetts Institute of Technology and Gregory Neumann, NASA Goddard Space Flight Center, and their team produced the global Mars digital terrain model (DTM) from the Mars Global Surveyor (MGS) Mars Orbiter Laser Altimeter (MOLA) that was used to simulate the images. Another archive of some of these images in ISIS formation were produced by Edmunds and Robinson (2003).

4.0 REFERENCES

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