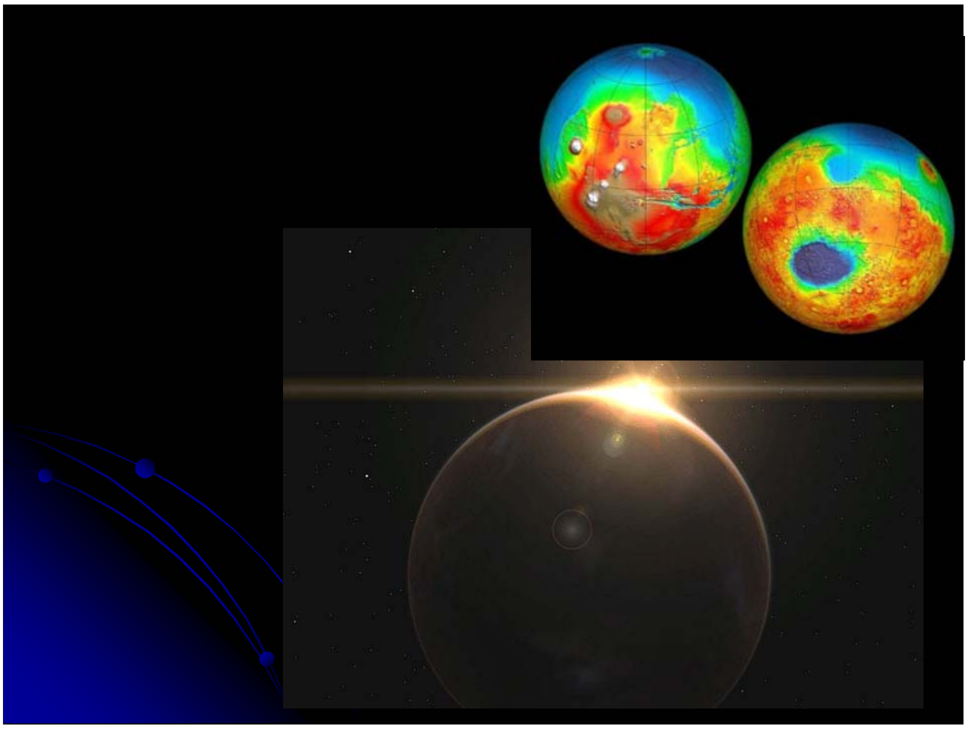
PROJECT CONCERNING REMOTE SENSING IMAGE ANALYSIS:

Using MOLA and MOC images to study geomorphology or topographic modification of highland/lowland dichotomy boundary of Mars.

Prepared by: Ahmed T Rahid



Remote Sensing Image Processing and Analysis.
Dr. Hongjie Xie

PROJECT OBJECTIVES

The Dichotomy Boundary is a reflection of crustal evolution, following (from Isidis to Tharis south of Elysium and Lucas Planum) a series of relic transform faults and spreading centers, elsewhere defined by catastrophic lava flows encroaching upon highlands terrain. Martian Dichotomy is a global feature separating the northern and southern hemispheres. The origins of the Dichotomy Boundary and the processes that have been responsible for it's modification since its formation have been a matter of debate and speculation. Part of difficulty in making significant advances on these problems has been the lack of new data. The recent focus on the exploration of Mars has considerably changed this and the prospect of even more new data promises to cast new lights upon the characterization and the topographic modification of highland/lowland dichotomy boundary of Mars and new insight into its evolution. The purpose of this project is to review some of this new data and to point out where new advances are likely to be made.

PROJECT OVERVIEW

The project is divided into four sections

1. Definition of crustal dichotomy boundary
2. Description of MOLA
3. Description of MOC
4. Integrating MOLA with MOC to study crustal dichotomy boundary

DATA SETS & METHODS

The dichotomy boundary and its topography are known to have undergone significant modification since its formation. The acquisition with Mars Global Surveyor (MGS) of very high-resolution images, The Mars Orbital Camera (MOC), (The Mars Orbital Camera will take high resolution images, on the order of a meter or so, of surface features. It will also take lower resolution images of the entire planet over time to enable research into the temporal changes in the atmosphere and on the surface.), (expected datasets are MOC narrow angle images (2-7 m/pxl)) and global altimetry, Mars Orbital Laser Altimeter (MOLA), (This instrument will measure the time it takes for a transmitted laser beam to reach the surface, reflect, and return. This time will give the distance, and hence the height of the surface. Combining these measurements will result in a topographic map of Mars. Expected datasets gridded MOLA topography (128 pxl/deg), and individual MOLA PEDR profiles) will help me to analyze these processes.

Sometimes the THEMIS images that have improved spatial resolution and spectral diversity may be used.

The individual datasets will be imported into ENVI 4.1 remote sensing and image analysis software for geo-registration, analysis and generation of map products. ISIS 3.1 software may also be used. Additional software to read the datasets may also be used from NASA ftp sites.

HIGHLAND-LOWLAND DICHOTOMY BOUNDARY

The crustal dichotomy boundary on Mars is a narrow region separating the cratered highlands, located mostly in the southern hemisphere of Mars, from the northern hemisphere's lowland plains. The cratered highlands stand two to five kilometers higher than the lowland plains, so the boundary is a relatively steep slope .The northern lowland is not only several kilometers lower than the southern highland, it also is surfaced by materials that are significantly younger than surface materials in the southern highland .The boundary traverses a somewhat sinuous path that encircles about 1/3 of the planets surface.

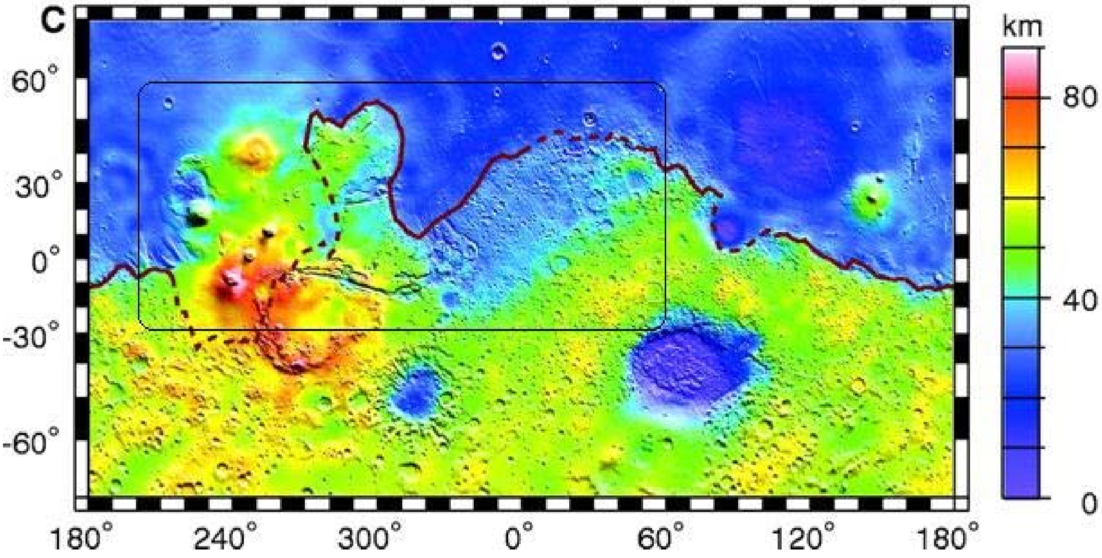


Figure 1: The dichotomy boundary traveling path shown along the dotted path with An emphasis in the square region.

It has long been known that the boundary between the northern lowlands and the southern uplands (the dichotomy boundary) is characterized by both a generally Distinctive topographic change, as well as characteristic geological units that appear to represent processes of weathering, topographic degradation and scarp retreat southward from the dichotomy boundary. A variety of terrains characterize the dichotomy boundary. At the largest scale, the southern uplands are characterized by a variety of Noachian-aged units, most prominently the Plateau and high plains assemblage of units, of which the Plateau sequence is the most important. Members of the Plateau sequence form "rough, hilly, heavily cratered to relatively flat and smooth terrain, covering most of the highlands". The most widespread of the units there are of Noachian age and include the heavily cratered units , the heavily cratered unit dissected by a higher density of valley networks , an etched terrain "similar to the cratered unit but deeply furrowed by sinuous, intersecting, curved to flat-bottomed grooves producing an etched or sculptured surface", and smoother intercrater ridged plains of possible volcanic origin. The surface of the northern lowlands, on the other hand, is largely covered by the younger Hesperian- aged Vastitas Borealis Formation, and older units are virtually absent at the surface. The intervening area between the southern uplands and the northern lowlands, commonly referred to as the dichotomy boundary, is a broad region hundreds of km wide that extends along the border and has a variety of units with a range of ages One of the most prominent units in association with this zone is Noachian-Hesperian, undivided This unit forms "closely spaced conical hills a few kilometers across whose distribution indicates that they are remnants of numerous craters." The unit also "forms rugged terrain on margins of cratered plateaus, and isolated remnants." The unit is gradational with the Amazonian-aged knobby plains material, where the two units adjoin, but hills in the HNu unit "are more closely spaced, larger, and occupy more that about 30 percent of the area." The HNu unit is interpreted as "eroded remnants of ancient cratered terrain Produced by mass-wasting processes, possibly as result of removal of ground ice..." Etched plains material is composed of irregular mesas and pits, and ranges from mid-Hesperian to mid-Amazonian in age later regional units obscure and heavily modifies large portions of the dichotomy boundary. Most prominent is the Tharsis volcanic complex which superposes and largely obscures the location of the dichotomy boundary from about 70W-140W. Just east of this, the Chryse basin and outflow channel complex obscures the boundary from ~15W to 70W. Hesperian-aged volcanic complexes, such as Syrtis Major, obscure the boundary regionally, such as along the western margin of the Isidis Basin (285W-290W), and Hesperian-aged regional ridged volcanic plains modify the surface at the boundary in Elysium Planitia (230W-265W), and in Deuteronilus Mensae (320W-355W), perhaps even underlying the Vastitas Borealis Formation throughout the northern lowlands (4). Finally, the thick mantling deposits of the Medusae Fossae Formation cover the dichotomy boundary in the Tharsis-Elysium Planitia region (125W-220W) to depths locally of several km.

One of the most prominent and aerially significant developments of this terrain occurs in the Deuteronilus Mensae region, extending ~1500 km from about 320 to 355 W, and occupying a band of terrain up to ~800 km wide along the northern lowland-southern upland dichotomy boundary. In this region, the terrain spans an elevation range from ~-4 km to ~-2 km. It is largely made up of fragmented and isolated islands of Hesperian ridge plains (Hr) and Noachian plains, where the fragments are large enough to map as specific outcrops, rather than components of a separate specific unit, as with HNu. Also mapped are large swaths of Apk, in the lows between the large islands, and preferentially toward the eastern edge of the region. A second major area of development is adjacent to Deuteronilus, extending eastward along the dichotomy boundary for about 2400 km from ~275 to 320 W to the Isidis Basin. Here the terrain is more knobby and occupies a 500-700 km wide belt that spans an elevation range from ~-3 km to ~0 km. East of the break in the dichotomy boundary formed by the Isidis Basin, the knobby terrain reappears in a swath at, and parallel to, the dichotomy boundary extending from the eastern rim of Isidis (~260 W) for about 4700 km to the vicinity of 180 W, before it becomes largely mantled by the younger Medusae Fossae Formation. In this region, the elevation range is about -2 km to 0 km.

From this region eastward, most geological units exposed at the surface are Hesperian and Amazonian in age and comprised of Hesperian ridged plains (Hr), Tharsis volcanic, and the Medusae Fossae Formation. There is local evidence that the fretted and knobby terrain may underlie these units but neither regional development nor continuity can be established from about 180 W to 55 W, in the vicinity of the Chryse Planitia. In the area of Chryse Planitia (~25-55W), there is little evidence for knobby terrain at the edge of the basin. Similar terrain, however, occupies a significant amount of the area south of the basin, extending from the mouth of Valles Marineris (Coprates Chasma at ~55 W) across western Margaritifer Terra, to ~15 W. This terrain is commonly associated with outflow channel formation, is mapped as Hcht (channel chaotic terrain) and is Late Hesperian in age. Completing the global traverse along the dichotomy boundary, we find that the last segment, Western Arabia Terra, extending from ~30 W to 355 W, is almost devoid of continuous exposures of knobby terrain. Fretted and knobby terrain also characterizes some of the area surrounding the Elysium Rise, primarily to the southeast, east and north, at elevations of ~-4 to ~-2 Km.

The transition between the major crustal provinces at Mars's hemispheric dichotomy boundary separates the older, heavily cratered southern hemisphere highlands from the relatively smooth, resurfaced, and younger northern hemisphere lowlands. The boundary zone has a width of ~700 km and is characterized by complex geology .In many areas, the dichotomy boundary also exhibits a regional elevation change, sometimes described as a scarp, with relief of up to 4 km over distances of 300 to 1300 km . In the longitude range 110° to 190°E, the transition from the northward thinning to uniform-thickness regions of crustal structure coincides with the dichotomy boundary. Most of the dichotomy boundary, however, does not correspond to the crustal thickness transition, and it is apparent that the geologic expression of the dichotomy boundary is not a fundamental feature of Mars's internal structure.

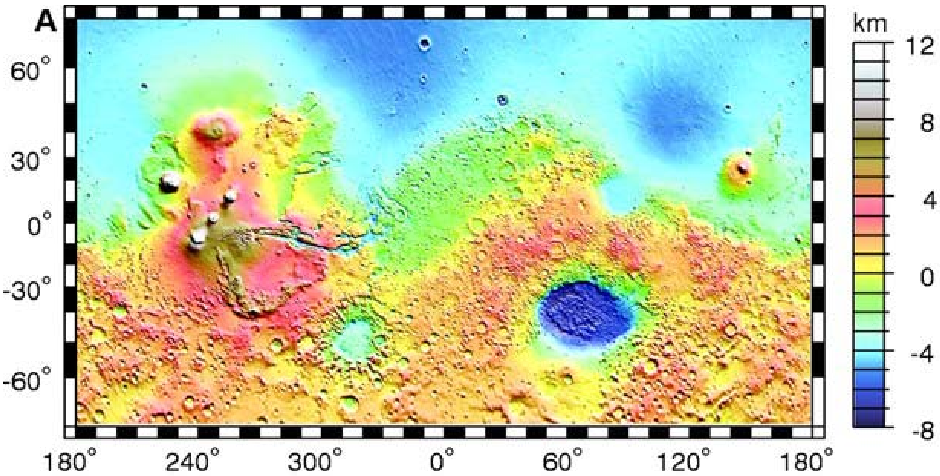


Fig 2: Topography around Dichotomy Boundary

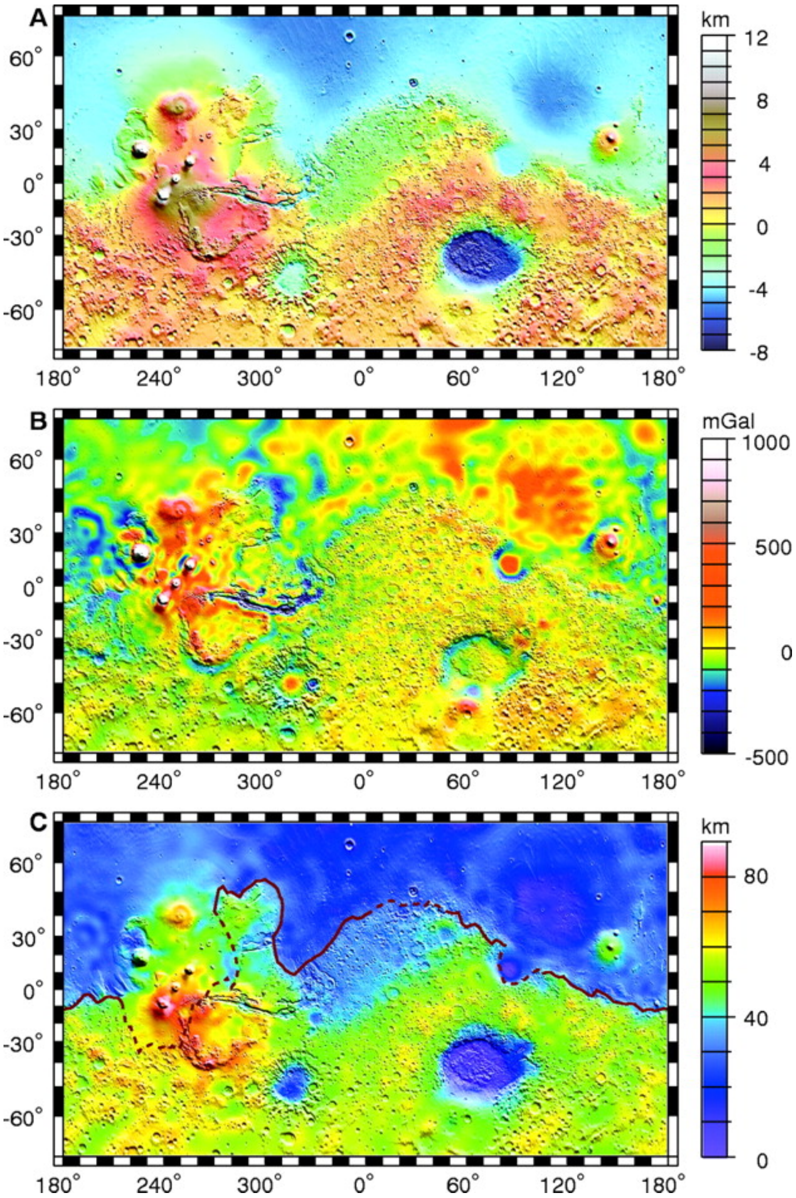


Figure 3: Global maps of (A) topography, (B) free-air gravity, and (C) crustal thickness of Mars (Mercator projection).

On all panels, the Tharsis province is centered near the equator in the longitude range 220° to 300°E and contains the east-west-trending Valles Marineris canyon system and the major volcanic shields Olympus Mons (18°N, 225°E), Alba Patera (42°N, 252°E), Ascraeus Mons (12°N, 248°E), Pavonis Mons (0°, 247°E), and Arsia Mons (9°S, 239°E). The Arabia Terra region is centered at 10°N, 10°E, the Elysium rise is at 30°N, 150°E, the Tempe Terra region lies at 40°N, 290°E, the Syria Planum region is centered at 25°S, 270°E, and the Terra Cimmeria region is centered at 60°S, 180°E. Major impact basins include Hellas (45°S, 70°E), Argyre (50°S, 320°E), Isidis (12°N, 88°E), and Utopia (45°N, 110°E). The hemispheric dichotomy boundary is shown as a red line in (C), solid where distinctively expressed and dashed where estimated. This analysis uses an areocentric coordinate convention with east longitude positive. One degree of latitude on Mars equals ~59 km.

MARS ORBITER LASER ALTIMETER

MOLA is the Mars Orbiter Laser Altimeter, an instrument currently in orbit around Mars on the Mars Global Surveyor (MGS) spacecraft. The instrument transmits infrared laser pulses towards Mars at a rate of 10 Hz and measures the time of flight to determine the range of the MGS spacecraft to the Martian surface. Range measurements have used to construct a precise topographic map of Mars that has many applications to studies in geophysics, geology and atmospheric circulation.

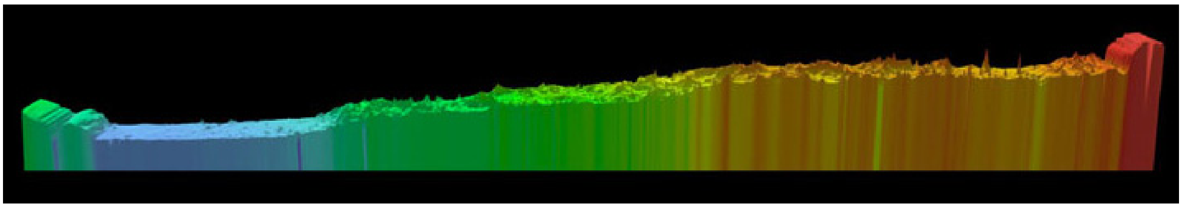


Figure 4: Pole-to-pole view of Martian topography from the first MOLA global topographic model .

The slice runs from the north pole (left) to the south pole (right) along the 0° longitude line. The figure highlights the pole-to-pole slope of 0.036°, such that the south pole has a higher elevation than the north pole by ~6 km. This global-scale slope was likely present for most of Mars' history and controlled the surface and subsurface transport of water indicated by images of outflow channels and valley networks. The regional high (in orange) in mid-southern hemisphere latitudes corresponds to the western edge of the topographic annulus that encircles the massive Hellas impact basin. In the figure warm colors correspond to high elevations and cold colors correspond to low elevations. Exceedingly flat northern hemisphere in blue.

The MOLA is designed to map the Martian global topography and can also be used to measure the height of water and carbon dioxide clouds. This information will be used for scientific objectives that include study of the surface processes on Mars including the formation and evolution of volcanoes, basins, channels and the polar ice caps. Also, combined with gravity and other data, one can study the structure and evolution of the interior of Mars, including the lithospheric thickness and strength, internal convection, composition, thermal history, and release of water and carbon dioxide to the surface. MOLA data can be used to calculate the volume and seasonal changes in the polar ice deposits, and to measure the altitude and distribution of water and carbon dioxide clouds, for the purpose of constraining the volatile budget in the Martian atmosphere.

The MOLA works by transmitting a laser pulse down towards the surface. The pulse is reflected off the surface (or cloud) back to the instrument, where the return is detected. The two-way travel time is recorded, giving a measure of the distance between the spacecraft and the surface. Corrections are made to this distance based on atmospheric effects, and accurate tracking of the spacecraft position allows an estimate of the surface altitude or cloud height. A large number of surface altimetry measurements will be taken and combined to produce a global topographic map.

The MOLA consists of a diode pumped, Q-switched Nd:YAG laser transmitter with pulse energy of 40-45 mJ. It can send continuous bursts of 10 pulses/sec, each pulse having a beam diameter of 1 cm and a divergence of 0.45 mrad. The receiver is a 50 cm parabolic antenna with a Si APD detector and four electronic filters (20, 60, 180, and 540 ns). The receiver field of view is 0.85 mrad with a 10° cone about the mirror exclusion.

The vertical resolution is 2 m local (relative) and 30 m global (absolute). The horizontal resolution is 160 m. The altimeter is run by a 80C86 microprocessor with 54HC family logic. The altimeter is mounted to the MGS instrument panel.

The MOLA instrument is functioning as a passive radiometer and is routinely sampling the 1064-nm radiance of the Martian surface. Measurements are collected once a second and have a resolution of approximately 300 m x 3 km.

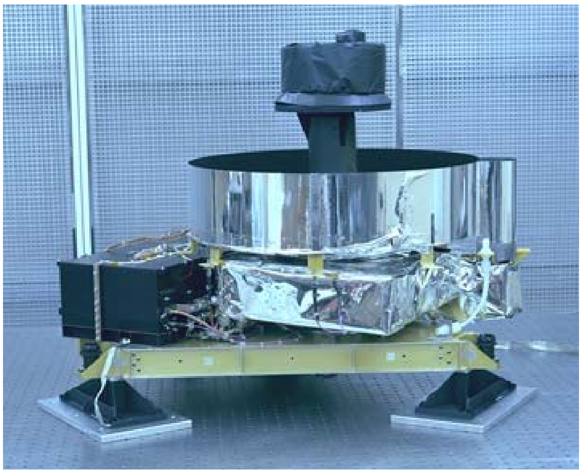


Figure 5: The Mars Orbiter Laser Altimeter (MOLA).

MOLA has not collected altimetry data since June 30, 2001, when the instrument oscillator stopped. Without the oscillator the laser does not receive fire commands. At the time of the oscillator anomaly, MOLA had been in space for 1696 days, and had undergone 216 power-on/off cycles. The MOLA laser had fired 671 million times in space and MOLA had made about 640 million measurements of the Martian surface and atmosphere. Until the anomaly, the laser energy had been nominal and steady at about 20 mJ/pulse. The June 30 event was the first anomaly in MOLA's operation since the MGS launch in November 1996 .

To measure the radiance of the Martian surface, the MOLA receiver is used to measure optical power at 1064 nm scattered by Mars within its receiver field-of-view. MOLA's passive radiometer mode was built into the instrument, but was previously used only to automatically adjust the settings of the ranging receiver thresholds. Passive radiances were collected throughout the MGS Mapping and Extended Mission, and these observations are only now being processed for scientific use. In the passive mapping mode, the instrument has been optimized for measuring radiance, and the instrument now has greater sensitivity than it did when used for ranging. Radiance measurements are being relayed back to Earth in the same manner as the altimetry data. The first data collected by MOLA in radiometer mode has been processed, calibrated and documented, and is undergoing review by the NASA Planetary Data System.

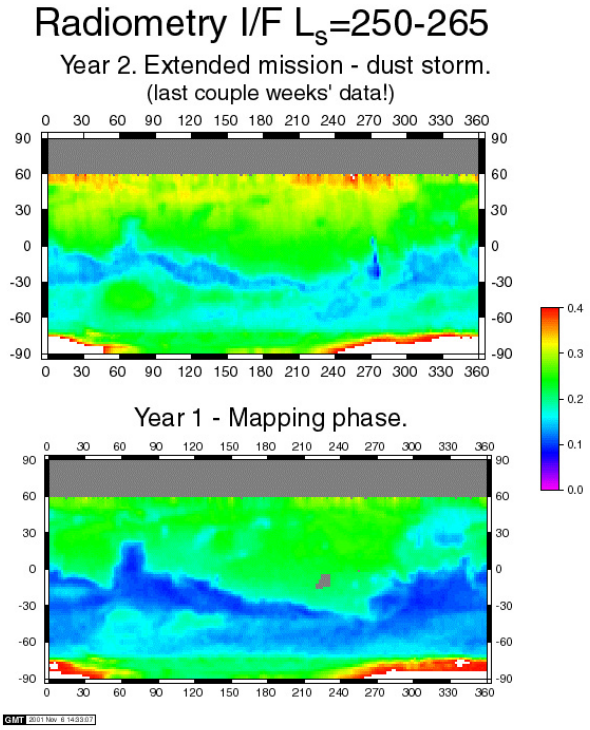


Figure 6: MOLA Radiometry Data

The MOLA instrument has the ability to measure the reflectance of the Martian surface at 1064 nm in a passive mode, *i.e.,* without use of the laser or ranging function. Reflectance is measured from background noise counts that in ranging mode are used to set the detection threshold of the instrument on a once per second basis. Passive data have been collected since MOLA began operating at Mars in 1997 and were used in an operational sense to adjust the detection threshold to optimize the range measurement. But until the oscillator ceased function during the summer of 2001, the MOLA reflectance measurements were never analyzed in terms of their science value. The attention of the science team has now turned to operating MOLA as a single channel radiometer.

MOLA began mapping the surface of Mars in passive mode on October 9, 2001. In radiometry mode the instrument has been optimized to increase the sensitivity of passive reflectivity measurements compared to those passive measurements that were collected while the instrument was in altimetry mode. This optimization entailed slightly modifying the data collection strategy and downlink data stream. For one thing, the software was patched in order create data packets using the spacecraft oscillator. Consequently, the finest resolution of passive measurements is limited by the spacecraft clock's 8-Hz rate.

Here is a comparison of MOLA passive measurements obtained in altimetry mode and radiometry mode.

Table :1: Comparison of MOLA Measurements

Parameter	Radiometry Mode	Altimetry Mode
Frequency	8 Hz	1 Hz
Resolution	375-m along track	3-km along track
Noise statistics	10^4 counts on 2 channels	Log counts

S/N	100:1	10:1
MGS Pitch Angle	16°	0° (Nadir viewing)
Profiles Collected	1533	About 9000
Geolocation	Rectified to 1/16°	About 100 m

To achieve the highest sensitivity during ranging, the MOLA receiver detection threshold was dynamically adjusted to be as low as possible while maintaining a pre-determined false alarm rate. The average false alarm rate is monitored in real time on board MOLA via a noise counter, whose output is input to the threshold control loop. The false alarm rate at a given threshold is a function of the detector output noise, which is the sum of the detector shot noise due to the background light seen by the detector and the dark noise. Noise counts are accumulated via a single high sensitivity "pixel" within MOLA's 0.8-mrad field of view for the spectral region of 1064 nm. The brightness of the scene viewed by the MOLA detector varies and depends on the sun-Mars distance, the solar illumination angle, atmospheric backscatter and attenuation conditions, and the surface reflectivity at 1064 nm.

The MOLA noise counter output is a function of the received solar optical power reflected off Mars surface and the MOLA detection threshold. The relationship between the three is given by an integral equation that can be evaluated numerically. The radiance of Mars can then be determined by dividing the optical power by the solid angle subtended by the MOLA receiver telescope, the optical bandwidth, and the Mars surface area within the receiver field of view. The phase angle corresponding to the sun-Mars-MOLA angle is available from the MGS database. Using this approach the MOLA team is now analyzing passive observations obtained during the MGS mapping and extended mission when the instrument was in altimetry mode as well as in the E2 mission with the instrument in radiometry mode.

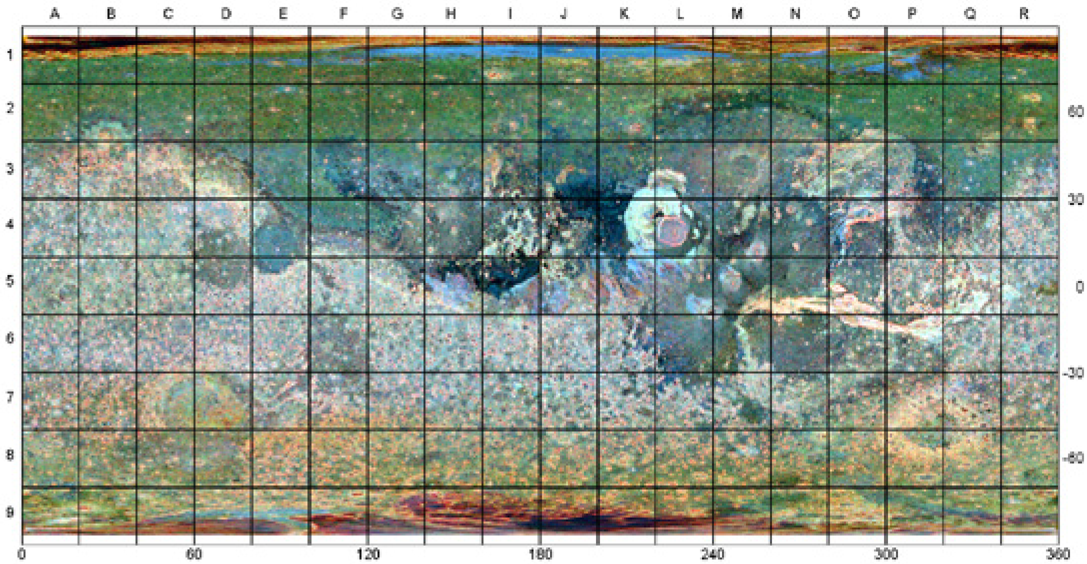


Figure 7 : MOLA Radiometric maps.

The above map is of kilometer-scale surface roughness of Mars in cylindrical projection (top), and in polar Lambert azimuthal equal-area projection for the northern (middle) and southern (bottom) hemispheres. The maps are composite RGB images. The median absolute values of the differential slopes at 0.6-, 2.4-, and 19.2-km baselines are used as the blue, green, and red channels, respectively. Brighter shades denote a rougher surface

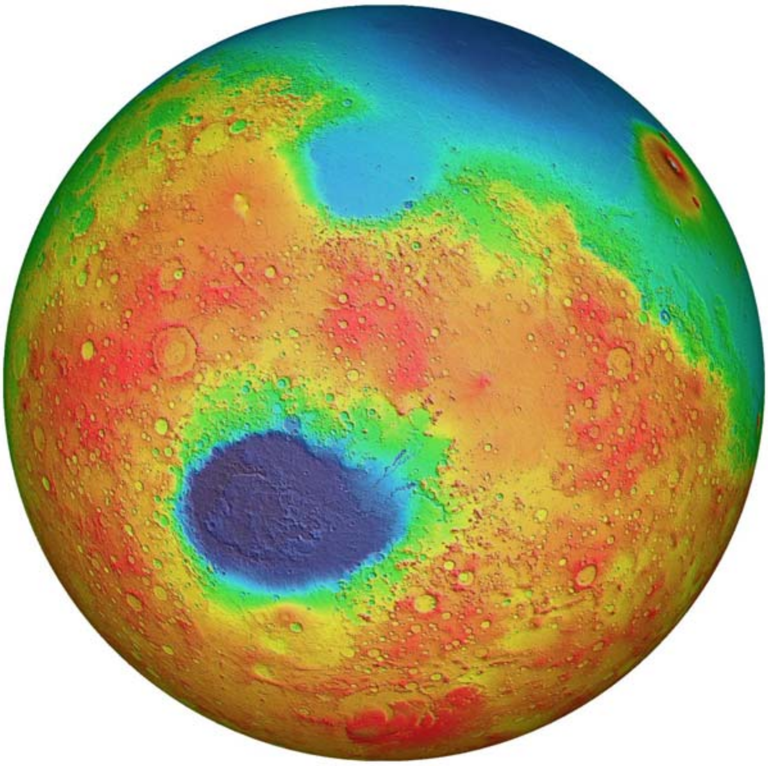


Figure 8 : Global false-color topographic views of Mars at different orientations from the Mars Orbiter Laser Altimeter (MOLA).

The maps are orthographic projections that contain over 200,000,000 points and about 5,000,000 altimetric crossovers. The spatial resolution is about 15 kilometers at the equator and less at higher latitudes. The vertical accuracy is less than 5 meters.

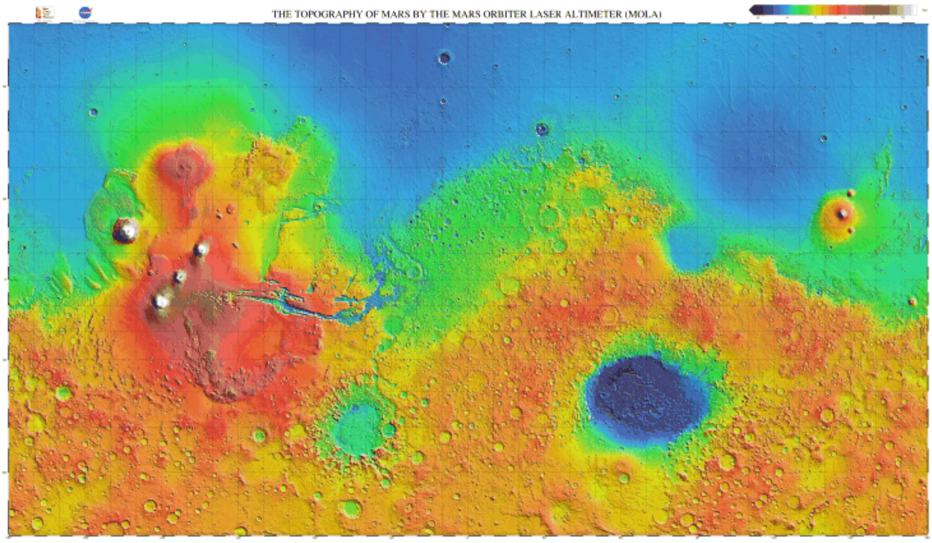


Figure 9 : Very high resolution topographic shaded relief map of Mars

MARS ORBITER CAMERA

MOC is a dual-mode camera which works like a television camera but instead of taking videos, it takes still pictures.

MOC consists of three cameras:

1. A narrow angle system that provides grayscale high resolution views of the planet's surface (typically, 1.5 to 12 meters/pixel)

2. Red and blue wide angle cameras that provide

. daily global weather monitoring,

. context images to determine where the narrow angle views were actually acquired,

. regional coverage to monitor variable surface features such as polar frost and wind streaks.

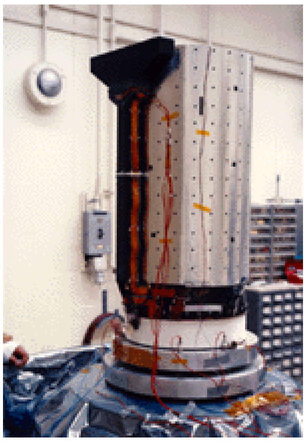


Figure 10 : Mars Orbiter Camera

The MOC experiment is designed to obtain images of the surface and atmosphere of Mars for studying the meteorology/climatology and geology. Its primary objectives are to:

1. obtain global, synoptic views of the Martian surface and atmosphere on a daily basis in order to understand the meteorological and climatological changes during the mission
2. monitor surface and atmospheric features for changes on temporal scales from hours to years and on a spatial scale necessary for resolving the details of their morphology
3. systematically examine local areas at high spatial resolution so that surface/atmosphere interactions and geologic processes which operate on short time scales can be quantified

The electronics for the MOC are completely redundant and the narrow-angle and wide-angle cameras can be operated by either set of electronics and all three cameras can be operated simultaneously. The camera is controlled by a 32-bit (10 MHz, 1 MIPS) SA3300 microprocessor with four ASICs, 128 kb EPROM, and 192 kb SRAM. Because of the high volume of data which imaging experiments can generate, the MOC electronics contain not only a large amount of memory (~12 MB DRAM buffer) for processing and storing the images, but also have the capability of utilizing a number of data compression techniques (both lossless and lossy). Further, the MOC can transfer these data (either to the on-board recording system or via real-time transmission) at any rate of which the spacecraft is capable. As a result, the equivalent of two, four, or eight (depending on mission phase) 2048x2048 pixel images can be processed on record-only days and, once every three days on average, 14 such images can be processed and sent during an eight-hour real-time pass. In-flight calibration of the MOC is extremely limited due to the fixed pointing of the instrument. Some opportunities for in-flight calibration are possible during regional or global dust storms. Otherwise, pre-flight measurements made to characterize the instrument performance comprised the bulk of the instrument calibrations. Available data rates are 700, 2856, 9120, and 29260 real-time bits/sec.

Finally, due to the MOC's large capacity for the storage and processing of images, it is intended to be used as part of the Mars Relay, which will provide a communications link between other Mars missions and the Earth.

Most of the data volume from Surveyor will be generated by a dual-mode camera called the Mars Orbiter Camera (MOC). This device works like a television camera, but will takes still images instead of motion video. In narrow-angle mode, MOC's black and white, high-resolution telephoto lens will spot Martian rocks and other objects as small as 1.4 meters (4.6 feet) across from orbit. These pictures will be sharp enough to help scientists conduct detailed geological studies without setting foot on the planet.

In contrast to the detailed surface images, MOC's wide- angle, global monitoring mode will use a "fish-eye" lens to generate spectacular panoramic images in color spanning from horizon to horizon. These pictures will resemble weather photos of Earth commonly shown on late-night news broadcasts. NASA will release many of these images on a public access, "information super-highway" called the Internet almost as soon the radio signals carrying the pictures reach the Earth.

Using hundreds of these panoramic photographs, scientists all over the world will be able to play them like a motion "flip- book" or a film. This ability will allow them to see the life history of Martian weather phenomena such as dust storms, cloud formations, and the growth and contraction of the polar ice caps. In addition, these time-lapse animations will allow scientists to keep track of surface features that get blown by the wind, such as dust streaks and sand dunes.
The datas from MOC are mainly available in two formats

- Full-size decompressed but otherwise unprocessed image in PDS .IMG format; and
- Full-size data set in raw MOC compressed (PDS .IMQ) format

Mars Orbiter Camera images are identified by a 3-character mission subphase descriptor, followed by a hyphen, followed by a 5-digit numerical identification.
During the Aerobraking and Science Phasing Orbits subphases of the mission in 1997 and 1998, the 5-digit numerical identifier was based on orbit number (defined by periapsis point) and numerical sequence of image commanded for that orbit. For example, an image identified as AB1-10905 was taken during the Aerobraking-1 subphase on orbit 109 and it was the 5th image taken by MOC during that orbit.

The first full Mars year of imaging from the mapping orbit was called the Mapping Mission. The Second full Mars year was called the Extended Mission; the third Mars year is designated by the MOC team as the Relay Mission because data were relayed through the MOC buffer from the Mars Exploration Rovers during this period. During the Mapping Phase of the mission -- including the Calibration (CAL) and Fixed High-Gain Antenna (FHA) subphases and the subsequent subphases designated M00, M01, M02, M03, M04 (and so forth), the 5-digit identifier indicates the numerical order in which the image was commanded during that subphase. For example, an image identified as M03-00006 was the 6th image commanded during mission subphase M03. The Mapping Phase ended with subphase M23 on January 31, 2001, and the Extended Mission Phase began. Extended Mission images begin with the prefix "Exx" in which "xx" is a number indicating the month from the start of the Extended Mission (e.g., the first month of Extended Mission, February 2001, is E01, the second, March 2001, is E02, etc.). The Relay Mission (third Mars year) began January 1, 2003; that month was designated R01, February 2003 was R02, and so forth. The Science and Support Mission (support for Mars Reconnaissance Orbiter aerobraking; fourth Mars year) began December 1, 2004, with S01. Subsequent months in the fourth Mars year of MOC operations are designated S02, S03, and so forth.

Image IDs within a mission subphase are in numerical, time-sequential order based upon the start time for each commanded acquisition. The numbering scheme is independent of the camera used (narrow angle, red wide angle, or blue wide angle) at any point within the sequence. Wide angle context frames are not separately commanded, but rather are autonomously commanded when the camera is told to acquire a context frame for a commanded image. Wide angle context frames are given the ID number immediately following the ID of the commanded image, even though their acquisition begins earlier than the narrow angle image. Gaps in the numbering sequence (e.g., a skip from image 01002 to 01009) usually indicates images that were commanded but never received on Earth; they can also, especially in subphases M09 through M12 and R13 through R19, indicate data from the Mars Relay antenna used for the Deep Space 2, Mars Polar Lander, and Mars Exploration rover missions. Loss of images can result from any number of problems, including those that occur onboard the spacecraft as well as at receiving stations on Earth.

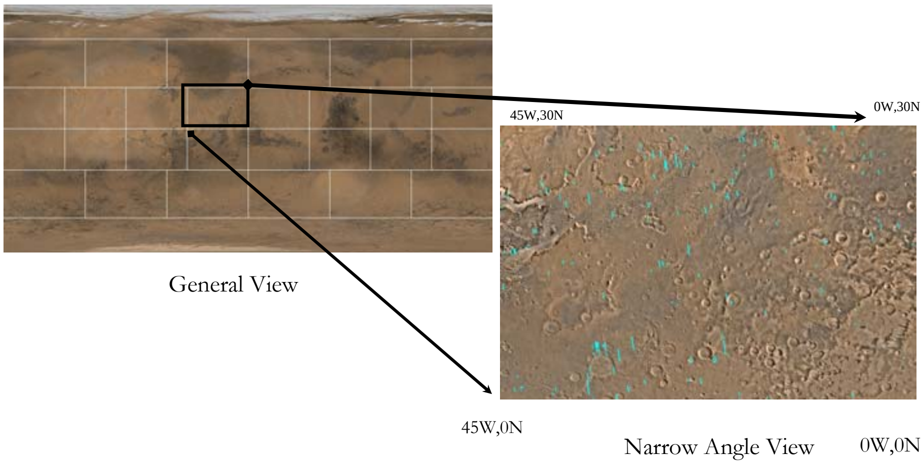


Figure 11 : MOC narrow angle images

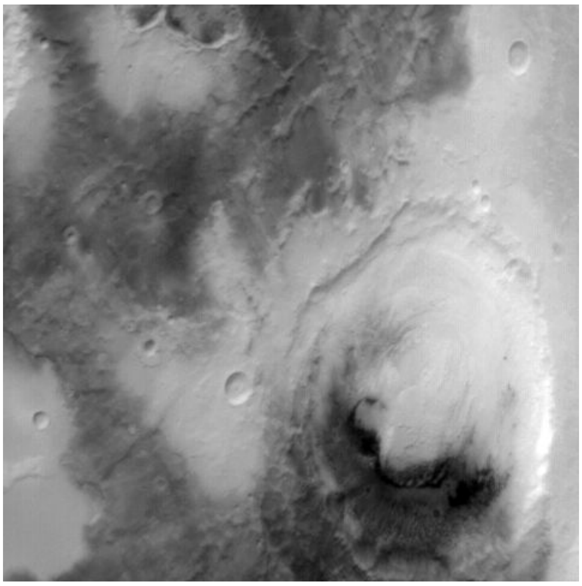


Figure 12 : MOC wide angle image

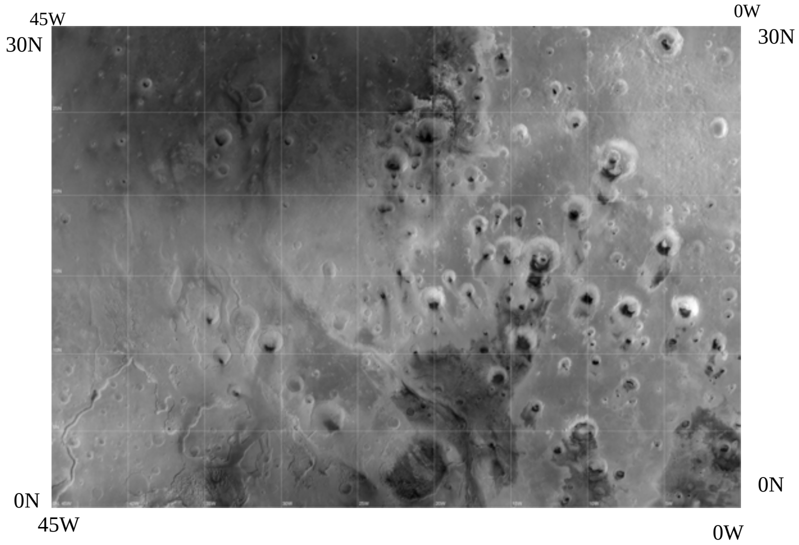


Figure 13 : MOC wide angle image of Mars

COMBINATION OF MOC AND MOLA IMAGES

MOLA collects accurate laser altimetry data over the Mars surface whereas MOC acquires high resolution images. The processing MOLA range data results in a global digital elevation model at ground spacing 1/64 degrees. However, many Mars site-specific studies require higher resolution topographic information. For this purpose, MOC images need to be processed based on photogrammetric principle along with MOLA data.

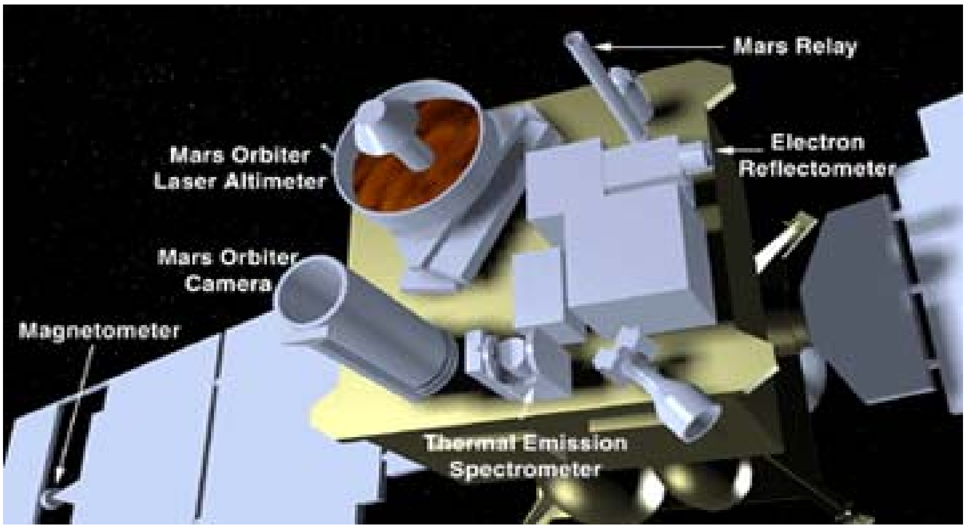


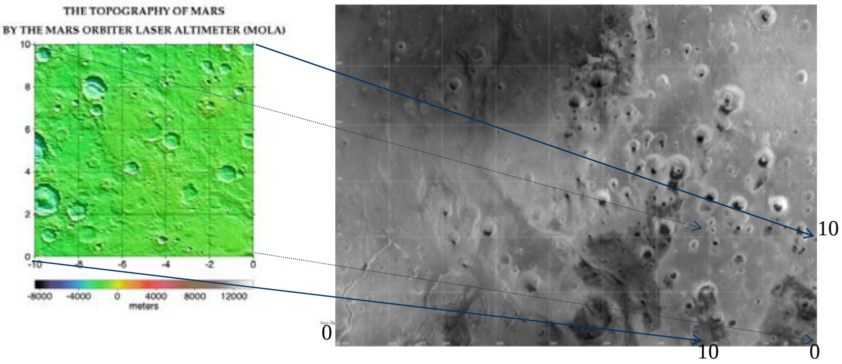
Figure 14 : MOLA and MOC in the Mars Global Surveyor

The primary MGS mission objectives are to collect data about Martian surface, atmosphere and magnetic properties and to build a comprehensive dataset for future mission planning. MGS mapping instruments include Mars Orbiter Laser Altimeter (MOLA) and Mars Orbiter Camera (MOC). MOLA data is considered to be the most accurate mapping data at present with absolute accuracy around 10 meters vertically and around 100 meters horizontally). MOC, a linear pushbroom sensor system, provides up to 1.4-meter high resolution images with its narrow angle (NA) camera and 280-meter low resolution images with its wide angle (WA) camera in blue and red bands.

We can use the two sets of data in a combine way by aligning MOLA profiles to MOC images by empirically matching topographic features. MOC and MOLA images do not coincide properly with each other. The same MOLA points are located on different features in the MOC stereo images. This mis-registration is found nearly to be a constant shift mainly along the flight direction.

MOLA is designed to understand global three-dimensional topography and atmosphere around Mars using laser signals. If MOLA data and MOC images are
obtained at the same time, the MOLA profiles are called simultaneous MOLA profiles. Thus, one MOC image has one linear-pattern MOLA profile.

So if MOLA and MOC images are to be used in combination, geo registration of the two images and ground control point selection are very important factors. Furthermore, the orientation of the MOC image plane is also a very important factor.



Details from MOC wide angle map

Figure 15 : Comparison of MOLA and MOC images.

We can observe it from the above figure that some features of the MOC images do not coincide with the MOLA image properly.

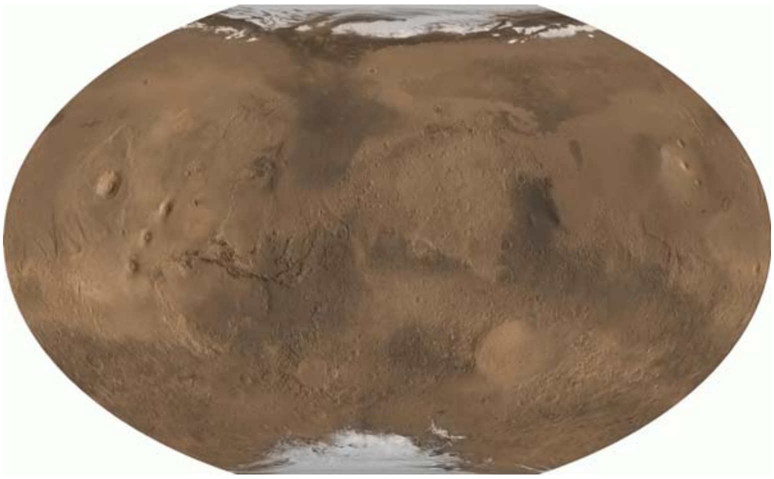


Figure 16 : Map of Mars combining MOC and MOLA data

This map of Mars was produced in a collaborative effort by the Mars Global Surveyor MOLA and MOC teams for the *National Geographic Society*. It is an image of Mars that incorporates over 200 million laser altimeter measurements from MOLA and about a thousand wide-angle images from MOC. The altimetry accentuates details on the surface not visible in images due to the dusty atmosphere of Mars, and the image data provides realistic color. The image projection is Winkel-Tripel.

So in light of the above discussion we can see that, The MOC images provide high spatial resolution observations of morphology, but each image covers a very small portion of the surface. On the other hand, MOLA observations are global, but relating the various roughness measurements with specific surface features can be difficult.

The MOC image is invaluable for context and landform information--especially on smaller scales while the MOLA topography is essential for the landform shape and slope information.

By combining these observations we can

a) provide a means of relating the MOLA roughness measurements to specific surface morphology and

b) scale the MOC observations across the regions between observations.

CONCLUSION AND RECOMMENDATION

- Though a vast amount of pre-processed and also raw data were available, lack of knowledge and experience and also time constraints have made it impossible to provide a final processed outcome.
- Though combination of MOC and MOLA images were used previously to study other areas of Mars, this combination of MOC and MOLA data were never been used to study the dichotomy boundary region of Mars.
- An accurate and consistent registration between MOC images and MOLA data is needed for a refined outcome because MOC and MOLA coordinates do not sufficiently coincide. The outcome can then be used to generate local and high resolution digital elevation model. As the first and also fundamental step, ground control needs to be selected for MOC images.
- Extensive study and pre-processing concerning trajectory data and sensor geometry need to be done for the registration of MOC images to a MOLA profile.

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