Air and Space this Week

Item of the Week

Mariner 9: A Pivotal Mission

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Sunday, ***November 14****, marks the* ***50th*** *anniversary of the Mars orbit insertion of the* Mariner 9 *spacecraft. This was a truly pivotal mission! Not only was it the first time that a spacecraft was put into orbit around another planet, the data it returned fundamentally altered our perception of the Red Planet, and taught us all an important lesson about drawing conclusions on incomplete data.*

Solar System exploration by spacecraft started at about the same time manned spaceflight did, and the Mariner program was a big part of that. Mariner 9 *was the most impactful of the 10 Mariner missions, by far.*

The Mariner Program

NASA expanded President Kennedy's charge to "put a man on the Moon, before the decade is out" to include robotic exploration of the Solar System. As was the case for Mars (here), Solar System exploration is very difficult. The very cutting edge of technology is required, operating under extreme conditions. And the Mariner program is an example of that dictum.

There were 10 missions in the Mariner program: Three of the ten were complete failures, which was a pretty good batting average back then!

Spacecraft	NSSDCA ID	Launch Date	Target	Outcome
Mariner 1	MARIN1*	07/22/1962	Venus	Destroyed by the RSO at Launch
Mariner 2	1962-041A	08/27/1962	Venus	Success – First interplanetary Fly-by, 10 years to the day before Apollo 17 left the Moon
Mariner 3	1964-073A	11/05/1964	Mars	Failure due to Launch Shroud Failure to Deploy
Mariner 4	1964-077A	11/28/1964	Mars	Success! See here also
Mariner 5	1967-060A	06/14/1967	Venus	Success
Mariner 6	1969-014A	02/24/1969	Mars	Success
Mariner 7	1969-030A	03/27/1969	Mars	Success
Mariner 8	MARINH*	05/08/1971	Mars	Failure of Second Stage

Mariner 9	1971-051A	05/30/1971	Mars	Spectacular Success!
Mariner 10	1973-085A	11/03/1973	Mercury	Success: Three Fly-bys

*Neither *Mariner 1* nor *Mariner 8* lived long enough to get an official NSSDCA ID number

And now, some background.

Before Mariner: A Telescopic View of Mars

The distance between Earth and Mars varies from 54.6 million to 401 million kilometers, depending on where Earth and Mars are in their orbits. The distance between the two planets reaches a minimum about every 26 months, when Mars is at "opposition" to the Earth (meaning that Mars-Earth-Sun is a straight line). Because Mars' orbit is a bit elliptical, the distance between the two planets at opposition varies by ~18%. The best oppositions for observing Mars with a telescope occur when Earth is near aphelion and Mars is near perihelion, and those opportunities come every ~17 years.

A good telescope can reveal many features on the martian surface during those favorable oppositions, and mapping the surface features on Mars in the 1800s was pursued rigorously. English astronomers drew what they saw and named the features after prominent English people. French astronomers did the same, but named features after famous French people. The situation in the sky mirrored the world's political situation. Nobody could agree on any unified naming scheme; the International Astronomical Union, which now governs such things, did not exist yet. What to do?

It fell to an Italian, Giovanni Schiaparelli, to come up with a solution (grudgingly) accepted by all. He was an astronomer of considerable skill, but he was also a scholar of classical antiquity. Instead of naming the features he mapped for famous people of the day, he instead named them for features on Earth they resembled. But he didn't use the present-day names for the terrestrial analogs, he used names from the distant past. We use his naming scheme as much as possible to this day. Thus we have both Syria and Sinai on Mars, but we also have Ausonia (an old name for Italy), Hellas (an old name for Greece), Chryse (an old name for Burma), and Hadriaca (an old name for the Adriatic), etc. Alas, his names have largely survived, but the features he ascribed them to were almost all misinterpreted; for example, Hadriaca – the martian Adriatic, was not a sea but rather turned out to be a volcano, as did his analog to the Tyrrhenian Sea. The one he got almost fully correct he called Nix Olympica, the "Snows of Mt. Olympus," which turned out to be temporary clouds over Mars' largest mountain, Olympus Mons, the tallest volcano in the Solar System.

Mars was proving to be a most interesting place! But although Schiaparelli was an astute observer, working with one of the best telescopes in the world, he would be fooled by an optical illusion. His eye-brain combination played "connect the dots" on him when he looked at the mottled martian surface under the very best observing conditions. Instead of seeing the surface as it was, he perceived it to be covered with a network of more-or-less straight lines.

Being a good scientist, he gave them a neutral name, *canali*, which in Italian means "channels," a feature that could be formed by natural processes.

But "canali" is very close to the English "canal," which are not natural, but are things made by humans. The Suez Canal had just been built. So here we had a learned astronomer, respected by all, talking about features on Mars that had to be created by some sort of intelligent life…

Popular Pseudoscience

Schiaparelli did not push the misperceived view, but others did. The most noteworthy of the bunch was one Percival Lowell, of back bay Boston. He traveled broadly in his youth, and was exposed to the work of Schiaparelli, and his imagination was fired by the thoughts of intelligent Martians. He knew that astronomers had seen polar caps on Mars come and go with the changing seasons, and that areas adjacent to the polar caps seemed to show a seasonal change of color, too. He envisioned the canals to be a planetary-scale public works project, where water-hungry Martians built enormous canals to irrigate the parched soil of the Red Planet.

Lowell was a gifted author, and he wrote several very popular books where he expounded his beliefs. He used his wealth to build an observatory in Flagstaff, Arizona, which is still in operation today, where he could make observations of his beloved canals.

The scientific community reacted with a bemused skepticism, for, after all, Lowell was not a scientist and he most definitely did not follow the established process of scientific inquiry. Instead of observe, classify, hypothesize, and refine, Lowell decided what was "true," then sought evidence to support his pre-conceived notions, trumpeting those observations that supported his beliefs and ignoring those that didn't.

Now we had a respected astronomer, and a rich guy, both talking about Martians and canals, and the public bought it, big time. Things did not improve when other authors horned in on the act, notably Edgar Rice Burroughs of Tarzan fame, who wrote a series of (terrible) books about John Carter, who could transport himself to "Barsoom" magically, where he had a number of exciting, and improbable, adventures.

H.G. Wells didn't help the scientific cause, either, with the publication of his "War of the Worlds." The public panic following Orson Welles' dramatic radio version of the book in 1938 showed how deeply the public believed in, and feared, intelligent and evil Martians. Although, personally, I still like Marvin!

During the Cold War, Mars and the threat of malevolent Martians enjoyed popularity, with Martians playing a substitute for the Commie threat, a Red (planet) Scare. By the 1960's, many people expected Mars to be (have been) inhabited, and canals to be real, constructed, watercourses.

Mariners 4, 6, and 7

Spacecraft in the 1960s were very primitive, so NASA usually launched them in pairs so as to have total redundancy. It proved a good policy. *Mariners 1* and *2* were targeted on Venus, so

even when *Mariner 1* failed, *Mariner 2* still gave the country a chance for its first exploration of another planet by robotic proxy. [BTW: Exactly ten years, to the day, elapsed between *Mariner 2*'s fly-by and the making of the last (for now) human footprint on the Moon!]

The same pairing tactic worked with *Mariners 3* and *4*, and *Mariners 8* and *9*. *Mariner 5* and *Mariner 10* were solo shots, and *Mariners 6* and 7 were both successful.

Mariner 4 was humanity's first close-up look at the Red Planet. It returned only 22 images, covering a total of ~1% of the martian surface. The mission was a success in many ways, but to the public, it was a bust, because the photos it sent back showed Mars to be more like the Moon than like Barsoom. But the images were pretty low-resolution, so maybe… I covered the *Mariner 4* mission in more detail in an earlier Item of the Week; see here.

Mariners 6 and *7* carried a more sophisticated camera system than did *Mariner 4*. There were two cameras on each spacecraft, one with a wide-angle lens that acquired images 1000 km on a side, showing details as small as 3 km, and one with a narrow-angle lens, acquiring images 100 km on a side showing details as small as 300 m. Between them, the two spacecraft returned 75 near-range photos of the surface, covering ~20% of the martian surface. They showed that while the surface of Mars was heavily cratered, like the Moon, many of the craters seen were shallower than their lunar counterparts. They also showed that Mars did have a polar cap, but it was made of dry ice (frozen CO2), not water, and that the atmosphere was predominately CO2 also and very, very thin. The notion that Mars was a present abode of life took a hit, but lived on in the minds of the public.

The Race to the Moon, and the Race to Mars

The race between two competing political systems was expressed in the sky, not the battlefield. Which system could get to the Moon first, ours or theirs? And the Moon was not the only target of competition in 1969, Mars was, too. It was looking more and more like the Americans would win the former, and the Russians managed to save some face by conducting three successful robotic sample returns.

Russia could get another chance to demonstrate symbolic superiority with the Mars launch window opening in 1971.

The United States was planning two complementary Mariner missions to Mars for a 1971 launch. The Russians countered with *Mars 2* and *3*. All four spacecraft were to be placed into Mars orbit, the first time any planet had been orbited by a robotic satellite. But the Russians were planning to one-up the U.S., for their two spacecraft also had a lander component, with a tethered walking rover no less! The landing capsule would separate from the main spacecraft prior to orbit insertion and operated independently.

Mars 2's landing capsule crashed, making it the first human-made thing to "land" on the martian surface. *Mars 2* was inserted into Mars orbit on November 27. *Mars 3* did better, its lander made it to the surface OK, but it only returned data for a few seconds before going silent. The *Mars 3* spacecraft was inserted into orbit on December 2. [The *Mars 3* lander came

in during a raging dust storm. Moving particles often build up static electrical charges, so perhaps the *Mars 3* lander's electronics got "zapped."]

The two Mariners had been planned to complement each other so as to maximize information returned. But when *Mariner 8*'s second stage failure killed the spacecraft, scientists and engineers worked feverishly to adjust the *Mariner 9* mission profile to cover both spacecraft's previous goals as best as possible.

Mariner 9 was inserted into Mars orbit on **November 14, 1971**, almost 50 years ago, beating out the two Russian spacecraft to be the first man-made object to orbit another planet.

But there was another problem facing all three orbiters. Long-range photography showed that the martian atmosphere was opaque, and no surface features could be seen, almost certainly due to a planet-wide dust storm. All three orbiters could see nothing. What an anti-climax!

The Russians were doubly vexed by this development. Their orbiters had pre-programmed photographic sequences that could not be altered from Earth, and they dutifully returned a number of images of a featureless Mars. *Mariner 9*, on the other hand, could at least try to wait out the dust storm.

The Real Mars Revealed!

Suspense was building among the imaging team members as the days passed without Mars' atmosphere clearing enough for *Mariner 9* to see the martian surface. Then four dark spots appeared, three in a line with another off to the side. What could they be? The leading idea was that they were the tops of mountains tall enough to be seen above the diminishing dusty layer. Image team members teased fellow member Carl Sagan by referring them as "Carl's Marks."

The marks were, indeed, the tops of mountains. As the dust cleared, the enormous size of the mountains shocked everyone. Even more impressive came with a more detailed look at the summits of the mountains; each one had a large crater atop it, and some had multiply-nested craters. They looked just like Hawaiian mountains, large basaltic volcanoes.

Linking the features now appearing on the martian surface to maps prepared from telescopic observation was one of the tasks of the imaging team. The location of the volcano "off to the side" matched exactly to the site of a feature Schiaparelli called "Nix Olympica," the "Snows of Mt. Olympus." He was almost all right. It wasn't snow, it was intermittent clouds. The official name was changed to "Olympus Mons" (Mount Olympus).

Mariner 9 kept imaging the surface as the atmosphere cleared, and the features revealed were amazing. Not only were there Hawaiian-style volcanoes, there were both river and flood-type channels, a tectonic rift valley the size of the United States. Even more intriguing, there were dark areas whose appearance changed over time. They were called "variable features."

Dean B. McLaughlin, an astronomer, studied telescopic images in the 1950s of the dark areas on Mars that some were suggesting were irrigation-supported patches of vegetation. He hypothesized that they could be volcanic ash or other particulate material being shifted about

by martian winds. And Dean proved to be correct. There were sand dune fields and other wind-related features all over the planet.

Mars is about half the size of Earth, meaning that its surface area is one-fourth that of Earth. But since the Earth's oceans cover about three-fourths of its surface, that means that the surface area of Mars is about the same as the land area of the Earth. *Mariner 9* data showed that ***every*** geological process that operates on Earth is, or has, operated on Mars.

Volcanism: Both planets have Hawaii-type volcanism, volcanic plains volcanism, and pyroclastic volcanism. The scale is different in some cases; Olympus Mons has ~50 times the volume of all of the Hawaiian Islands and the chain of volcanic islands and seamounts to their northwest, including the parts underwater!

Tectonism: Both planets have expressions of tectonism at different scales. The Earth has a network of large-scale features reflecting plate tectonics. The giant rift valley, named "Valles Marineris" (Mariner Valley) in honor of *Mariner 9*, shows that large-scale fracturing of the martian surface has occurred. The alignment of the three large volcanoes near Olympus Mons also suggests that they are all on one large fracture. Both planets show evidence of faulting and folding on smaller scales.

Impact: Mars has areas with a lot of large craters, and areas that are relatively smooth, indicating that geological events served to erase craters in some areas preferentially. It is also peppered with a number of small craters. Earth has craters, too, but its active geological processes tend to erase them quickly. Very few, such as Arizona's Meteor Crater, retain their initial shape; most of the few hundred craters we've identified are the eroded roots of the original impact feature. Crater distributions have been one of the best tools for assessing the relative ages of different areas on Mars (and other bodies, too!).

Gradation (the action of erosion, gravity, wind, and water): Both planets show evidence of all of the above, at least in the past. Mars was seen to have flood channels like the Channeled Scablands of the Pacific Northwest, meandering canyons like those in the American Southwest, and some dendritic (branching) drainage systems, too. Mars has areas covered by sand dunes, and hills whose shape has been sculpted by wind erosion, just like on Earth.

Canals: The *Mariner 4* images strongly suggested that the "canals" were not real, but since the returned pictures only covered a small part of the planet, the issue was not fully settled, especially for the true-believers. The images from *Mariner 6* and *7* really hurt the "canal" hypothesis, and *Mariner 9* results buried the coffin.

A Good Reminder

Mariner 9's data showed Mars' true nature and how complex the Red Planet's geologic past had been. The lesson was clear: ***One cannot make planet-wide evaluations based on only seeing <20% of the planet's surface!*** It was just bad luck that the few pictures returned by *Mariner 4* were of a heavily-cratered zone rather than something like Valles Marineris, and that the pictures from *Mariners 6* and *7* did not reveal major surprises, either.

This lesson has been important in the exploration of the rest of the Solar System. For example, *Mariner 10* flew by Mercury three times, but the geometry of each encounter was similar and only a little over half of the planet was seen, so the conclusions based on Mariner 10 data had to always reflect that fact. Similarly, our understanding of the satellites of Uranus and Neptune has to be tempered somewhat by the fact that only one spacecraft, *Voyager 2*, has seen them up close. Since it flew by quickly, we weren't able to see all of their moon's surfaces well.

Not jumping to conclusions is as good advice to follow in science as it is in life!

What 50 Year Have Wrought

A large number of Mars missions have taken place in the half-century since *Mariner 9* first orbited Mars. Our understanding of Mars has moved forward accordingly. The Hi-Rise camera aboard the *Mars Reconnaissance Orbiter* has provided very-detailed imagery of much of the martian surface; the *Mars Orbiting Laser Altimeter* gave us detailed topographic info for much of the martian surface, and a series of increasingly-capable Mars robots have roved its surface. We are learning more about Mars every day, and how far our knowledge has advanced is just flat-out amazing.

Even though the data from *Mariner 9* has been surpassed by that from later missions, it was *Mariner 9* that opened our eyes to the interesting nature of Mars.

A number of now-senior planetary geologists "cut their teeth" on *Mariner 9* (and later Viking) data, too. In some cases, folks that had undergraduate jobs doing basic work on Mariner 9 data were inspired to work on Viking data in graduate school. Now they are key mission managers, scientists and engineers.

The importance of *Mariner 9* as a first step and the path we've followed was very much brought home to me personally by a statement made by my good friend Ken Edgett, now a senior scientist a Malin Space Science Systems, during the special Geological Society of America conference session honoring the career accomplishments of Jim Zimbelman. Ken is now the Principal Investigator for data returned by the MArs Hand Lens Imager (MAHLI) carried on the *Curiosity* rover. He was reflecting on Jim's career and thinking about how far we've come when he said, "I can remember as a kid seeing the variable features imaged by *Mariner 9* and how everyone was thinking about their possibly being related to martian winds, and now, fifty years later, with MAHLI, I can actually see individual sand grains being set into motion by martian winds!"

It's just been incredible! Imagine what the next 50 years might bring!

REFERENCES

Solar System Exploration Is Hard / The Mariner Program

Item of the Week for "Mars is Hard":
http://www.airandspacethisweek.com/assets/pdfs/20200803%20Mars%20is%20Hard.pdf

Spreadsheet of Mars Successes and Failures: http://www.airandspacethisweek.com/otherstuff.

A Wonderful Resource for Planetary Exploration: https://www.nasa.gov/sites/default/files/atoms/files/beyond-earth-tagged.pdf

NSSDCA Mars Mariner Missions: https://nssdc.gsfc.nasa.gov/planetary/mars/mariner.html

Mariner 4 images of Mars: https://www.nasa.gov/image-feature/mariner-4-image-of-mars

Mariner 6/7 images of Mars: https://mars.nasa.gov/resources/6773/mariner-6-and-7-images-plotted-on-global-view-of-mars

Mariner 9

Best resource: Hartmann, William K. and Odell Raper, 1974, *The New Mars: Discoveries of* Mariner 9, NASA Special Publication 337. Google Books here.

Ezell E.C. and L.N. Ezell, 1984, *On Mars: Exploration of the Red Planet 1958-1978*, NASA SP-4212. Reprinted 2009, ISBN-13: 9780486467573

Sheehan, William, 1996, *The Planet Mars: A History of Observation and Discovery*, University of Arizona Press, Revised 2021 with James Bell as co-author, ASIN: B09H2M1CNJ; See also here.

NSSDCA *Mariner 9* page: https://nssdc.gsfc.nasa.gov/nmc/spacecraft/display.action?id=1971-051A

Siddiqi, Asef, Beyond Earth: A Chronicle of Deep Space Exploration, NASA Special Publication 2018-4041. Here: https://www.nasa.gov/connect/ebooks/beyond_earth_detail.html

Mariner 9's 50th launch anniversary: https://www.nasa.gov/feature/50-years-ago-mariner-9-launches-to-orbit-mars

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NASA Chronology of Lunar and Planetary Exploration: https://nssdc.gsfc.nasa.gov/planetary/chronology.html

Mars Reconnaissance Orbiter: https://mars.nasa.gov/mro

HiRise Camera: https://www.uahirise.org

Mars Orbiter Laser Altimeter: https://attic.gsfc.nasa.gov/mola

MAHLI: https://mars.nasa.gov/msl/spacecraft/instruments/mahli

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