Air and Space this Week

Item of the Week

Mariner 4

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Next year will be a big one for Mars exploration. Operationally, three spacecraft are presently en route *(as covered by this former Item). Historically, 2021 is an important anniversary year, marking the 50th anniversary of* Mariner 9 *at Mars (an upcoming Item topic), the 45th of the* Viking *landings (ditto), and the 10th of the launch of the* Mars Science Laboratory *(aka* Curiosity*).*

I am sure there will be a lot of information about the three missions on their way to Mars for an arrival next February. I want to make sure that you have access to basic information about them and about the rich history of Mars study, so I'll be posting a number of Mars-related Items in the coming installments of A+StW.

Earlier this month, fifty-six years ago, *Mariner 3*, a primitive (by today's standards) spacecraft sat atop an Altas-Agena missile at Cape Kennedy, poised to be America's first attempt to visit Mars. The Mariner spacecraft series was the result of a significant visionary planning by NASA for planetary exploration, tempered by economic and technological limitations. Mariner's primary launch vehicle comprised an Atlas booster with either an Agena or a Centaur upper stage, giving enough oomph to go to any of the inner planets.

The first two spacecraft in the series were earmarked for Venus, because the Centaur was not yet available and the Agena upper stage that was available was not powerful enough to reach Mars, even with a reduction in size of the Mariner spacecraft. The Agena could reach Venus, so that was the target for the first two Mariners, in 1962.

Mariner 1's launch vehicle went awry shortly after launch and had to be destroyed by the Range Safety Officer (22 June 1962). *Mariner 2* fared better, and successfully made the first-ever visit to Venus on 14 December 1962. [BTW: It was one decade later, to the very day, that the last (for now) human footprint was made on the Moon! Note that ***only a decade*** elapsed between the time of John Glenn's Mercury flight (which occurred few months before the launch of *Mariner 3*) and the final footprint. That's about the same amount of time to date of the *Curiosity* mission!).

The next two Mariners were to go to Mars. Unfortunately, the powerful Centaur upper stage was still not ready in time for the 1964 launch window, so *Mariners 3* and *4* had to be down-sized further to accommodate the smaller booster. In spite of engineering and budgetary constraints, these must have been an exciting time for the wizards at JPL figuring out how to

build a technological infrastructure that would allow the examination of the bodies of the Solar System!

Hopes ran high for the launch of *Mariner 3* on 5 November 1964, but after the rocket had done its work properly, the spacecraft's protective aerodynamic shroud failed to jettison as planned, dooming the mission. Engineers had done some amazing work after the launch failure of *Mariner 1* to find and correct its fatal flaw, so that *Mariner 2*'s flight could be successful. After the loss of *Mariner 3* they turned-to again, figured out the problem with the shroud, fabricated a metal replacement for the original fiberglass, and quickly prepared *Mariner 4* for launch on 28 November 1964.

Mariner 4 represents one of those rare opportunities in scientific exploration for knowledge to make a giant leap forward. We had never seen Mars up close before. Earth-based observations had shown the scientific community that the real Mars could not be the Mars of John Carter or *lebensraum*-seeking three-legged beasts without viral immunity. Evidence had been building for more than a decade that Mars was less-hospitable as hoped, but the scientists wanted to see Mars up close in order to better understand the basic properties of Mars and its surface. But the public saw things differently, due in no small measure to the writings of Wells, Verne, Percival Lowell, and Chuck Jones, who spun fanciful tales of strange beings, exotic princesses, desperate-for-water canal builders, and the dreaded-but-never-competently-applied firepower of the Illudium Q-36 Space Modulator.

Think for a moment about the state of things in 1964. The first Beatles' albums hit the charts like a ton of bricks. Whiskey a Go Go opened on Sunset Strip, with Johnny Rivers leading its house band. Willie Mays broke the $100K salary line in baseball. The 24th Amendment to the Constitution was ratified. And that was just in January! The rest of the year was also momentous. The Klan murdered several people. LBJ won re-election over Arizona's Barry Goldwater. Martin Luther King won the Nobel Peace Prize. Robert Moog invented a very cool musical "instrument." Craig Breedlove made a six-mile-long skid mark at Bonneville. The SR-71 made its first flight. And Pete Townshend destroyed his first guitar.

That was the societal setting for our first foray at Mars.

The launch, achievement of a low Earth parking orbit, and then injection into a Mars transfer trajectory went so smoothly that only one mid-course correction was required. The spacecraft flew by Mars over the midnight (UT) boundary, the fly-by thereby occurring officially on both July 14 and 15, 1965.

Mariner 4 carried a more sophisticated suite of instruments than the previous three Mariners. A total of seven instruments, plus a TV-type camera, were aboard. The seven were designed more for the study of the Van Allen trapped radiation belts and the then-unknown nature of the interplanetary environment than the study of Mars. [If you follow the link above and count carefully, you know I'm leaving one item out. More later.]

One of the biggest objectives of the *Mariner 4* mission was to test the operation of a spacecraft that far from Earth, especially since so many of the earliest satellite and Solar System missions

would fail. Another critical objective was to assess the possibility of life on Mars. Some even expected to see canals!

NASA and JPL tried to conduct expectation management by pointing out that the spatial resolution of the TV-type camera on *Mariner 4* was insufficient to reveal any direct evidence of life. [If *Mariner 4* had flown by the day-side of Earth at the same distance it flew by Mars, its camera would not have revealed any signs of life, either. Insert your own joke about the inability to detect "intelligent" life on Earth here.] But some, almost exclusively outside the scientific community, still expected to see canals, plowed fields, cities, etc.

Most of the instruments aboard *Mariner 4* worked as designed, and those that did were successful in getting their data back to Earth. The camera was able to acquire 21 images, and part of one more, in a discontinuous path across the martian globe. The total area imaged was about 1% if the total surface area of Mars.

If *Mariner 4* were human, its feelings would no doubt have been hurt badly by the reaction to its fly-by of Mars, an almost total success after a most arduous journey. The images returned were necessarily of low quality, but they clearly revealed the presence of large flat-floored craters, not unlike the big impact features seen on the Moon.

The notion that Mars was more Moon-like than Barsoom-like was a major league letdown for those wanting a science-fictiony Mars. There was a massive drop-off in public interest in Mars exploration now that everyone knew there was no Marvin to meet us or substitute commies to vanquish.

The scientific community was let down, too. They weren't expecting a teeming mass of Martians, but the notion that Mars was merely a bigger, more distant version of the Moon was most disappointing, even if it wouldn't deter planning for future Mars missions. The Moon was old and dead, no longer geologically active; was that all there would be to Mars as well?

Problem was, those 21+ images *Mariner 4* returned covered ***only ~1%*** of the planet.

Mars has a radius about a half of the Earth, meaning that its surface is about a quarter of the size of Earth's. But remember, the Earth's land area is only about a quarter of the Earth's total surface. In other words, the surface of Mars is about the same size as the land area of the Earth….

Would you get an accurate representation of the Earth's land surface if you only could see a randomly-selected 1% of it? Suppose your photos covered only the Russian steppe, or the Great Plains of the USA – would that give you a representative view? What about if you only received images of the Himalayas?

We only had a few images; future spacecraft were planned that would give us more. But over-generalizing what little knowledge we could gain from *Mariner 4* was difficult to avoid.

Understanding more about the martian atmosphere was essential to working out Mars' history, in spite of the craters. One of the images acquired of the limb of Mars showed a distinct layer of haze of some sort aloft, but it was becoming increasingly obvious that Mars' atmosphere was

very thin, indeed, less than 10% of our own. Understanding more about Mars' atmosphere would also affect future mission planning, because if the martian atmosphere was as rarified as *Mariner 4* confirmed, then parachutes alone couldn't land a spacecraft lander safely.

You've heard me say NASA does the nearly-impossible, on time and (usually) on budget, and ***they do it with style***. Here's another example. I think.

The *Mariner 4* experiment that did not require a specialized instrument was the Occultation Experiment. I have heard two stories about it, slightly, but significantly, different from one another. A number A+StW recipients have expert knowledge of Mars exploration and its history, so if any of you can shed light on the following part of the discussion, PLEASE let me know!

The orbital planes of Earth and Mars align pretty closely, and it takes a lot of extra energy (thrust and fuel) to have a Mars transfer orbit that rises out of the Earth's equatorial plane. That means that when *Mariner 4* flew-by Mars, it would appear to pass *behind* Mars as seen from Earth.

A lot of research was being conducted on what happens to radio waves when they pass through a planet's atmosphere. One avenue of that work dealt with the attenuation and modification of the signal as a function of atmospheric density and structure. One way to get such changes in a signal would be if a spacecraft sending the signal could be made to pass behind a planet while its signal would be monitored for changes. All with early 1960's technology.

Here's the point of contention. The way I have heard the story, *Mariner 4* was planned, built, and launched. **WHILE the spacecraft was *en route* to Mars**, the radio guys at JPL realized that as *Mariner 4* would be eclipsed by Mars, the radio signal's attenuation as it passed through Mars' atmosphere would yield clues as to the overall thickness of the atmosphere and some indication of its structure. They quickly applied for funding as a bonus *Mariner 4* experiment and got it, even though their experiment required no instrument other than the radio already on board. Their idea worked perfectly, the data so received were valuable, and we have used that technique many times since to make similar important observations (*e.g.* here and here). That's why "Occultation" is listed as a mission experiment, as foreshadowed above. Talk about innovative thinking!

Alas, I have not been able to confirm the part of the story where the technique was worked out and the experiment was planned AFTER the launch of *Mariner 4*. There is ample confirmation that the technique was worked out theoretically before the launch, but I cannot find a confirmatory reference for WHEN the experiment was adopted by the mission. Was it as stated above, or was the Occultation Experiment planned from the get-go? Or was it a combination of both: Engineers realized that the occultation experiment was possible before launch and the experiment was "authorized" and funded after launch?

To me, this question is more than just an odd twist of ancient history. If the Occultation Experiment was planned (and funded) along with the other experiments, it's still a nice bit of science and engineering but not an example of "doing it with style" necessarily. But if the

possibility to conduct such an experiment arose *after* the spacecraft was launched, and then elevated to a mission objective, then it is an early example of the type of innovative thinking and rapid adjustment NASA would become well-known for.

Here's a salient passage from https://radioscience.jpl.nasa.gov/publications/dsn.html:

> "The history of radio propagation studies goes back to the early 1960s. Von Eshleman of Stanford University first proposed the method in 1962. Independently, a JPL team led by Dan Cain, conducting a study of the effect of refraction in the Earth's atmosphere on the accuracy of the counted Doppler, realized the possibility of applying the sensitivity of Doppler phase measurements to the study of the atmospheres and ionospheres of other planets (Kliore et al., 1965). The theoretical technique was developed largely by Fjeldbo (1964). The occultation techniques were demonstrated for the first time in 1965 when Mariner IV flew by Mars; they were used to determine the salient features of the Martian atmosphere, showing that the atmosphere is predominantly CO2 and that the surface pressure is less than one percent of that of Earth, or an order of magnitude less than had been previously believed…"

The two references in the passage above indicate that the concept of using radio occultation was known before the launch of *Mariner 4*, and was confirmed in action by *Mariner 4* during its fly-by. But the passage above does not say if the 1964 work *inspired* the inclusion of the Occultation Experiment as part of the mission, *prior to launch*. BTW, Kliore was the PI of the Occultation Experiment, and both lead authors of the cited papers were co-authors on the other. The key references are now hard to get; see the section below.

We have a very good understanding of the structure of the martian atmosphere today, due to radio occultation measurements by the many Mars spacecraft in the 50 years+ since *Mariner 4*. But *Mariner 4*'s contributions did not end with the fly-by. It acquired a lot more data than it could transmit to Earth in real time, so the data were recorded then downloaded to Earth after the fly-by, a process that took about a week; the full set of images was released on 29 July. The spacecraft was turned "off" on 1 October 1965. The time *Mariner 4* took to get to Mars was about twice that taken by *Mariner 2* to reach Venus, showing that robotic spacecraft could get the job done. It had performed so well that engineers wanted to learn more about how well spacecraft components operated after a long time in interplanetary space, especially its thrusters, as part of the preparations for the *Mariner 5* mission to Venus. So *Mariner 4* was turned back "on" for thruster tests, which were successful; NASA maintained contact until 31 December 1967 in order to make long-term measurements of the solar wind, in coordination with *Mariner 5* that year. For more info, see the Siddiqi link below.

NOTE: As related above, I have tried to find proper documentation regarding just exactly when the *Mariner 4* Occultation Experiment was added to the *Mariner 4* mission plan. I suspect strongly that the Kliore et al 1965 paper cited below will supply it, but that paper is difficult to access, at least without access to the JSTOR system (the first page of the article is available, but does not address how the Occultation Experiment came into being). ***Again, if anyone can help me track this point down, I'd really appreciate it!***

At the very least, the concept of radio occultation's value and the *Mariner 4* mission plan were contemporaneous, and *Mariner 4* is the first time this technique was used to explore another planet's atmosphere. The Occultation Experiment results showed that Mars' atmosphere was very thin (~1% of Earth's), likely unable to support life or an active hydrologic cycle.

One last point. *Mariners 6* and *7* would visit Mars using the next launch window (1967). The images they returned re-enforced the misperception that the *Mariner 4* images were a representative sample of the entire planet. However, a mere five years later, *Mariner 9* would prove that notion very, very wrong, and spectacularly so. Stay tuned!

Other references providing input to this Item include:

Siddiqi, Asif A. Beyond Earth: A Chronicle of Deep Space Exploration, 1958-2016. NASA History Program Office, 2018. Link: https://www.nasa.gov/sites/default/files/atoms/files/beyond-earth-tagged.pdf ***DOCENTS:*** ***This is a wonderful information resource on all Solar System exploration missions conducted in the time period covered!***

Kliore, A.K., Cain, D.L., Levy, G.S., Eshleman, V.R., Fjeldbo, G. & Drake, F.D. 20 scientific instruments (1965). Occultation Experiment: Results of the First Direct Measurement of Mars' Atmosphere and Ionosphere. Science 149, issue 3689, 1243-1248.

Fjeldbo, G. (1964). Bistatic Radar Methods for Studying Planetary Ionospheres and Surfaces. Stanford Electronics Laboratory, Stanford University, SU-SEL-64-025.

Fjeldbo, G. & Eshleman, V.R. (1968). The Atmosphere of Mars Analyzed by Integral Inversion of the Mariner IV Occultation Data. Planet. Space Sci. 16, 1035-1059.

Mariner-Mars 1964, NASA, SP-139, Wash., D.C., 1967 [This one is difficult to get ($).]

https://history.nasa.gov/SP-4212/ch3.html#table8 (On Mars: Exploration of the Red Planet, 1958-1978 – See Chapter 4) This book was co-authored by Lin Ezell, long-time friend of NASM, who successfully quarterbacked the construction of the NASM's Udvar-Hazy Center and was the founding director of the U.S. Marine Corps Museum. It's an outstanding resource, and should be on every Mars-o-philes bookshelf. [Google re-published the book in 2013, but they REALLY need to update the author bios on their website!]

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