Air and Space this Week

Item of the Week

RUSSIAN LUNAR MISSIONS

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The Space Race of the 1960s pitted NASA against the USSR Space Program. Who would be the first to achieve "firsts" and ultimately would land their astro/cosmonauts on the lunar surface? Superpower full-scale warfare was both unwinnable and unthinkable, but the Moon was a symbolic objective that would demonstrate the superiority of one system of government versus the other, thereby winning the hearts and minds of the rest of the world.

Like any good race, the contestants in the Space Race exchanged lead several times along the way. But by 1966 it was becoming clear that the USA was going to win, thereby accruing most of the tangible, semi-tangible, and intangible benefits.

*But the USSR was not without its important successes, too, late in the game. We've all heard about the six successful Apollo Moon landings, but did you know that scientists have samples from **NINE** locations on the Moon? The Russians never put astronauts on, or even around, the Moon, but they did conduct two successful lunar robotic rover missions and three successful robotic sample-return missions! This is their story.*

PLANETARY EXPLORATION TACTICS

Advances in exploration and the technology/techniques that enable it go hand-in-hand in a mutually-dependent manner. For example, astronomy made a leap forward with the discovery of the telescope; early telescopes were good enough to resolve (sorry) some scientific questions, but could only tantalize astronomers and generate questions that could be answered if the telescopes were just a bit better. New telescopes helped answered those questions but raised others requiring better investigative technology, and so forth. This ratcheting process continues to this day.

The exploration of the Moon and planets has progressed similarly. We could only go so far with our unaided vision, and increasingly-better telescope gave us some level of understanding of the nature of the Moon, at least its near side.

Once rocketry had advanced sufficiently, a step-wise approach to the direct examination of the Moon and planets took the following stages, not all of which have been achieved to date for all of the bodies of the Solar System. After examination from afar, the subsequent steps of exploration are more complex than those preceding:

Fly-by: A spacecraft is flown by the target one time (perhaps more), acquiring images and other data and radioing it back to Earth.

Hard Landing: A spacecraft is crashed into the target, taking and returning data until impact.

Soft Landing: A spacecraft is landed on the target, taking and returning data about the surface.

Orbiting: A spacecraft is put into orbit around the target, taking and returning data repeatedly.

Roving: A spacecraft lands on the target, and then (part of it) roams the surface (on the ground and/or flying above it) acquiring and returning data.

Sample Return: A spacecraft lands, acquires data and material from the surface of the target, and returns that material for examination on Earth.

Human Visitation: Humans land on the target, acquire data and surface material, and all return to Earth.

President Kennedy committed the United States to accomplishing all of the above steps for the Moon, "before the decade was out," in a speech to Congress on May 25, 1961. And NASA delivered, well-before the deadline.

The USSR tried to compete. The led in some parts of the "Space Race" early-on, and scored several "firsts," but never put a cosmonaut on the Moon's surface. However, a lot of folks do not know that the USSR successfully roved the Moon's surface (twice) and returned material from the lunar surface to Earth (thrice)!

THE USSR'S LUNA PROGRAM

The USSR's Moon program was difficult to understand in real-time because their government amplified successes and buried failures as much as possible; after all, the purpose of their Moon program was to demonstrate the superiority of the Soviet system. A lot of information has come to light of late, and historian Asif A. Siddiqi has compiled a lot of info about the earliest days of Spaceflight, theirs and ours, in his marvelous compendium, *Beyond Earth: A Chronicle of Deep Space Exploration, 1958-2016*; see here.

The USSR program to explore the Moon was quite aggressive, starting not long after *Sputnik* in 1958. Their program was the "Luna" series, comprising 24 named launches. There were more, but those that failed to reach at least Earth orbit were not given "Luna" designation.

THE FIRST FOURTEEN

The USSR's initial effort started in 1958, with a plan for four probes of the Moon, each with a different purpose. The first would be for an impact on the Moon, the second was to image the far side of the Moon, the third was to repeat the second with a more advanced imaging system, and the fourth was to hit the Moon with an atomic weapon to demonstrate USSR will and capability. Given the success of Soviet rockets from that period, the fourth would have been a much greater threat to Mother Russia than anyone else, on the Earth or the Moon. The first

rocket suffered a structural failure 93 seconds after launch, at Max Q. The second suffered an identical failure 105 seconds after launch. The third suffered a main engine pump failure and failed to make orbit. Cooler heads realized that A-bombs on unreliable rockets might be a bit premature, and repurposed the fourth launch as a simple impactor, without an atomic bomb. It became known as ….

***Luna 1*.** Well, at least the rocket worked. *Luna 1* was launched on January 2, 1959. But an error on the ground caused the booster to fire longer than desired, which caused the *Luna 1* spacecraft to miss the Moon by 6400 km or more. Instead, it became the **first** spacecraft to ever be launched into an orbit around the Sun.

Luna 2: The Soviets tried again to hit the nearside surface of the Moon with the launch of *Luna 2* on September 13, 1959. It worked, hitting the Swamp of Decay (Palus Putredinus) region off the Sea of Serenity. This was the **first** time any spacecraft had hit the Moon. Instruments aboard showed that the Moon had no significant magnetic field or radiation belts akin to the recently-discovered Van Allen Belts around the Earth. The impactor also carried Soviet medals and other such artifacts showing any who followed that the debris was Soviet in origin.

Luna 3 was the USSR's **first** attempt to image the far side of the Moon. It was launched on October 4, 1959 (exactly two years to the day after *Sputnik 1*). *Luna 3* was put into a highly-elliptical Earth orbit and actually used a gravitational assist from the Moon to get into position to image the far side, the first time a GA was used for any purpose. *Luna 3* was the **first** spacecraft to have 3-axis stabilization. The mission was a big success, returning crude images of the far side that showed a small mare area they immediately named the Moscow Sea and a dark-floored crater they named Tsiolkovsky after their first real rocket scientist (akin to our Robert Goddard); those names persist to this day.

Luna 4 was the first of the "second generation" lunar spacecraft, launched on April 5, 1963. It was placed in a parking orbit, then its rocket fired again to send it to the Moon. However, its navigation system failed soon thereafter, disorienting the spacecraft so that a mid-course correction was not possible, causing *Luna 4* to miss the Moon by over 8000 km. The Soviets were closed-lipped about it, but we know now that it was actually an attempt to soft-land on the Moon. *Luna 5* and *Luna 6* would be similar soft-landing attempts.

Luna 5 was launched on May 9, 1965. It suffered a gyro failure, which combined with a ground control error to cause the spacecraft to spin uncontrollably. It couldn't fire its descent rockets, and impacted the Moon in the Sea of Clouds.

Luna 6 was also done in by a ground control error (there must have been quite a collection of rocket controllers gulag-ing away in deep Siberia at this point!). It was launched OK on June 8, 1965, but a control error caused the main rocket, used for a planned course correction, to fire until its fuel was depleted, causing it to miss the Moon entirely. The surviving control personnel put it through its landing sequence anyway, as a test and practice. By the way, the Soviets planned to use an airbag system for the final stage of their lunar landing for this mission, and for:

Luna 7, another soft-landing attempt, was launched on October 4, 1965 (they loved that date, so did Beaver Cleaver). There was a failure in the attitude control system during the approach to the Moon, causing the landing rocket not to fire. The spacecraft hard-landed in the Ocean of Storms. No air bags could have saved it, but they did cause a landing failure for …

Luna 8, which was a somewhat more-sophisticated version of its immediate predecessors. Launched on December 12, 1965, it had a better navigation system, radio, ground control, and other telemetry, but one of its airbags leaked upon deployment at the start of the entry sequence. The lateral thrust caused by the escaping gas overcame the spacecraft's attitude control, which in turn prevented the landing rocket from operating. *Luna 8* hard landed in the Ocean of Storms.

Having a Swamp Castle flashback, perhaps? Not to worry…

Luna 9, launched on January 31, 1966, was a success. The navigation, airbag, and landing rocket systems worked, and the spacecraft landed softly in the Ocean of Storms near Marius Crater. This was the **first** time a spacecraft landed under control and intact on the Moon's surface. A number of pictures were returned from the landing site. The spacecraft measured radiation on the surface (low) and demonstrated that the lunar surface could support the weight of a spacecraft (no doubt disappointing Tommy Gold). NASA's first lunar soft landing, by *Surveyor 1,* would come almost six months later. The Soviets were initially closed-mouthed, but astronomers in England used the large radio telescope at Jodrell Bank to monitor signals sent by *Luna 9*, and noticed when the signals began including info in the international Radiofax format, meaning that the Soviets were sending images from the surface. The Jodrell Bank folks got a fax machine from the *Daily Express*, decoded the images, and published them before the Soviets did.

Next up for the USSR was an attempt to orbit the Moon that failed so badly that it did not receive a "Luna" designation. But the next attempt, ***Luna 10***, did succeed. It was launched on March 31, 1966, and went into lunar orbit, timed so that it would come around from behind the Moon just as the 23rd Congress of the Communist Party was convening its morning session. *Luna 10* carried a more sophisticated suite of instruments than that of any previous Luna spacecraft. Like its *Luna 9* predecessor, *Luna 10* beat its American counterpart, *Lunar Orbiter 1*, by over four months.

Luna 11 was launched on August 24, 1966. It was an instrumented orbiter that also had some engineering tests for future missions. It suffered an attitude control system failure after attaining lunar orbit, making it impossible for it to image he Moon or to make measurements with its other instruments. Its orbit decayed causing it to crash into the Moon a few months after arriving.

Luna 12, launched on October 22, 1966, was a virtual twin of *Luna 11*, but in this case, it made lunar orbit and operated successfully, returning a number of quality images and other data. Its radio finally failed after 602 orbits of the Moon, during which its orbit was slowly decaying. Controllers were able to raise it before loss of radio signals, but the Moon's "lumpy" gravity caused final orbit decay some time in 1967.

Luna 13 was a soft-lander, a slightly-improved version of the successful *Luna 9*. It was launched on December 21, 1966, and became the third successful lunar soft-landing mission (after *Luna 9* and NASA's *Surveyor 1*). It landed in the Ocean of Storms three days later, and returned three panorama images of the landing site, along with a lot of other data.

Luna 14 was the last of the "second generation" of Soviet lunar spacecraft, a sequence that began with *Luna 4*. It was an orbiter mission for which the primary mission was testing equipment and techniques needed for a crewed lunar mission. The spacecraft was similar to *Lunas 10*, *11*, and *12*. *Luna 14* operated for about 75 days in lunar orbit before its batteries died.

COMPETING WITH APOLLO

The Soviets had known for some time at this point that NASA was going to put astronauts on the Moon long before they could. But perhaps they could save some face with a successful lunar sample return mission, …

Luna 15, which launched on July 13, 1969, only a few days before *Apollo 11* launched. It was placed into an Earth parking orbit, then sent to the Moon on a relatively-slow trajectory, reaching lunar orbit on the 17th. The spacecraft ended up with an orbit significantly higher than planned. The landing attempt was delayed by concerns over the roughness of the planned landing site. Fifty-two lunar orbits later, a landing was attempted, but some undisclosed failure(s) occurred and *Luna 15* crashed on July 21, a day after *Apollo 11* landed.

The Soviets did get a consolation prize after losing the Race to the Moon. They did the next best thing scientifically, conducting a sample-return mission successfully, actually three of them (*Lunas 16*, *20*, and *24*), and two rover missions (*Luna 17* and *21*) which I'll cover below.

Luna 18 was planned as a sample-return mission, building on the success of *Luna 16*. *Luna 18* was launched on September 2, 1971, and made lunar orbit OK, but suffered an attitude control problem that caused it to crash on the Moon on September 7.

Luna 19 was an orbiter mission with two objectives: gathering data on the Moon from orbit and examining the near-Moon environment in preparation for crewed exploration. Launched on September 29, 1971, it made it to lunar orbit without problem, but its final engine burn to put it the planned orbit went awry, putting the spacecraft too far from the Moon for high-resolution imaging. *Luna 19* lasted for over 4000 orbits before its communications system failed.

NOTE: The Apollo program concluded successfully in December, 1972, between the launches of *Luna 20* (February 14, 1972) and *Luna 21* (January 8, 1973).

Luna 22, launched on May 29, 1974, was a mission very similar to that of *Luna 19*. It carried an array of sophisticated instruments and was able to conduct some important engineering tests. The spacecraft worked as planned until it finally ran out of maneuvering fuel on September 2, 2075, after which its orbit naturally decayed and it crashed on the lunar surface, likely in 1976.

Luna 23 was planned to be another lunar sample-return mission. Launched on October 28, 1974, it was damaged on landing and could not collect a sample for return. The Soviets landed *Luna 24* very close to *Luna 23*'s landing site.

SUCCESSFUL ROVERS AND SAMPLE-RETURN MISSIONS

The Soviets built on the success of their lunar soft-landers and developed landers with a mobile rover or (not and) landers that could reach out, collect a sample of lunar material, and return that material to Earth. Both were noteworthy engineering achievements given the prevailing technology of the time.

Luna 15, as mentioned previously, was supposed to get to the Moon, land, collect a sample, and return before *Apollo 11* could fully fulfill JFK's promise, but it failed. However…

Luna 16 did succeed in bringing back a sample, but it was more than a year after *Apollo 11*, and also after the success of *Apollo 12*. *Luna 16* was launched on September 12, 1970, into a parking orbit, then headed to the Moon, orbiting there five days after launch. From there it landed safely on the Moon on September 20, landing in the Sea of Fertility, sixty hours after the Sun had set at that location. A coring drill was deployed and its bit penetrated 35 cm into the lunar surface. A total of 101 g of material was collected and put into a sealed container. The rocket on the upper half of the lander fired on 9/21, and the sample landed three days later in Kazakhstan. The descent stage of the lander remained behind, collecting and returning temperature, radiation, and other data.

Luna 17 was a rover mission, launched on November 10, 1970. It landed successfully in the Sea of Rains and deployed the autonomous rover, *Lunokhod 1*. The rover carried a number of instruments and the supporting equipment needed to transmit data back to Earth. *Lunokhod 1* was a big success; it survived on the lunar surface for about a year, roved over 10 km, conducted over 500 regolith tests, and returned more than 20,000 images. It was solar powered, and had an ingenious set-up with a tub-like body, eight independently-powered wheels, and a lid for the tub that had solar cells lining the inner surface. It would rove during the day, stopping as necessary to open the lid and recharge batteries. A radiator mechanism kept the interior from overheating during the daytime movements. During the lunar night it would stop and close the lid tightly; a radioisotope heater would keep the interior sufficiently warm for *Lunokhod 1* to survive to the next lunar day.

Luna 20 was another sample-return mission, launched on February 14, 1972. It landed in the Sea of Fertility, collected a sample of lunar material, and returned it successfully. It had an improved version of the sampling drill used on *Luna 16*, but only returned 30 g of lunar material.

Luna 21 was a successful lunar rover mission, launched on January 8, 1973 (after the conclusion of the Apollo program the month preceding). It successfully carried the *Lunokhod 2* rover to its landing site in LeMonnier Crater. *Lunokhod 2* had better instruments and was in general more robust than *Lunokhod 1*. It roved over 37 km in four months of operation, returning 86 panoramic pictures and over 80,000 TV images of the lunar surface. It also carried a laser

retroreflector like that deployed by several of the Apollo Moon missions, which allowed the Earth-Moon distance to be very precisely determined. The *Lunokhod 2* mission was cut short, apparently because some lunar material managed to get inside the tub and interfere with the operation of the heat radiator, causing the interior to overheat. Communications was lost on May 10, 1973.

Luna 24 was the final mission of the primary Luna program. Like the previous successful sample-return missions, *Lunas 16* and *20*, *Luna 24* was designed to return samples. It was launched on August 9, 1976, and landed in the Sea of Crises nine days later. It functioned as designed, collecting 176 g of surficial material and returning them to Earth successfully.

The Soviets' lunar program came in second place to NASA's, but they did get to the next-to-final step in Solar System exploration, sample return.

Meanwhile, the Soviets continued their efforts to explore Venus and Mars. Their luck with Mars has been extremely bad (see here for a roster of their Mars missions and their outcomes). However, they enjoyed considerable success at Venus, leading NASA's efforts considerably in the 1970s and into the 1980s.

BACK TO THE MOON

"The successful Soviet Luna sample return missions returned small, but important, samples from three close locations on the Moon. In this new era of lunar exploration, several countries plan to soft land on the Moon over a much broader expanse of the lunar surface. China's *Chang'e 3* was the first robotic soft landing since ***Luna 24*** and *Chang'e 5* has brought back new extractions for the first time since 1976. India, Japan, and Russia plan to launch robotic missions in the coming years as well. And, of course, NASA is preparing to return humans to the Moon in the Artemis program." (Source)

Let's fast-forward 47 or so years. Russia planned to return to the Moon with a series of four missions, calling the new program "Luna-Glob." They named the first mission "Luna 25" to show continuity with their earlier efforts. Like the USA and China, Russian scientists were quite interested in exploring the south polar region of the Moon where there was some evidence of the presence of water. And they were ahead of the international competition, until…

Russian interest in returning to the Moon actually began in the 1990s, and some initial planning and design work that would lead to *Luna 25* began then, but languished, even after some attempts to secure collaboration with JAXA and ISRO. The failure of the Russian *Fobos-Grunt* mission to Mars/Phobos in 2011 set back the return to the Moon effort.

Assembly began in 2017. The initial plans for *Luna 25* called for a combined orbiter/lander mission, with the addition of two instrumented penetrator probes. The final design for *Luna 25* was simpler, a lander only with the primary mission of testing landing technology. The lander was to carry and array of scientific instruments, primarily to determine the composition of the lunar surface at the landing site. Later, collaboration with Sweden to include a surface instrument on *Luna 25*, but delays in the preparation of the spacecraft caused the Swedes to fly

their instrument on China's *Chang'e 4* lander, instead. Russia's invasion of Ukraine killed any other plans for international collaboration.

Luna 25 was launched on August 10, 2023. It successfully entered a lunar parking orbit on the 16th. Trouble began when the lander was commanded to start the landing sequence. A thruster involved fired 127 seconds instead of the planned 84, causing the lander to crash. NASA's *Lunar Reconnaissance Orbiter* imaged the impact site on August 26.

The future of the remaining three planned missions, *Lunas 26-28*, is uncertain.

Luna 26 is a planned lunar polar orbiter, as is *Luna 27*. *Luna 28* would be the next planned landing attempt, and will include a sample-return component. Launch dates for these three are tentative, starting no sooner than 2027.

Three additional lunar missions are being considered for the 2030s.

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Rovers and Sample Return

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