Largest explosion in space history rocks Tyuratam

On July 3, 1969, on the very eve of the Apollo-11 Moon landing, Soviet engineers made their second clandestine attempt to fly their giant Moon rocket. However, the mission ended just seconds after liftoff with a colossal explosion, effectively knocking down the USSR in the Moon Race, just days before NASA astronauts walked on the lunar surface.

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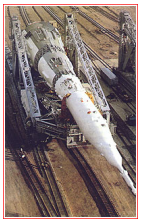
Escape rockets fire at the top of the doomed N1 No. 5L vehicle, as it begins a devastating collapse back to its launch pad.



Rollout of the N1 rocket to the launch pad. Credit: TsSKB Progress

The N1 No. 5L rocket and a full-scale mockup, known as 1M1, on the "Left" pad (background) at Site 110 in June 1969.

Second mission of the N1 rocket (No. 5L) at a glance (537):

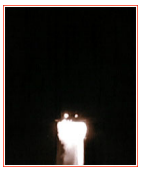
Launch vehicle designation	11A52 No. V15005
Payload designation	7K-L1A, L3S, 11F92 No. 4
Launch date and time	1969 July 3, 23:18:36.524 Moscow Time (537)
Maximum altitude reached	Approximately 200 meters
Flight duration	Approximately 23 seconds
Launch site	Tyuratam, Site 110, "Right" pad

The 5L vehicle on the pad.

The N1 No. 5L rocket on the "Left" pad at Site 110 at sunset. Click to enlarge.

The N1 rocket on the launch pad in Tyuratam. Credit: RKK Energia

The launch of the N1 No. 5L rocket on July 3, 1969. Credit: RKK Energia



An explosion

Besieged on many fronts

The first launch failure of the N1 rocket in February 1969 dealt a heavy blow to the Soviet space program, already hopelessly behind the US in the Moon Race. While engineers at Sergei Korolev's TsKBEM design bureau were picking up pieces, their Kremlin bosses watched the US to add to its triumphant flight of Apollo-8 around the Moon in the previous December yet another successful test of the Saturn-5 rocket during the Apollo-9 mission. Two months later, Apollo-10 hovered just a few miles from the lunar surface, setting the stage for the actual landing in the summer. Not surprisingly, new calls for changing the course came to the Kremlin.

Like in Khrushchev's reign at the turn of the 1960s, Vladimir Chelomei, the head of the rival TsKBM design bureau, reemerged on the scene with an "alternative" launcher to the troubled N1. Obviously, this time, there was no point in talking about beating Americans to the Moon, but instead, the Soviet response would be a manned mission to Mars! To this end, Chelomei proposed to upgrade his mighty but non-existing UR-700 rocket into an even bigger UR-900. (685)

However neither technical failures nor political pressure at home and abroad could deter Soviet engineers from pressing on with the N1 project. By that point, they had no illusions about winning the Moon Race, but the N1 still remained the centerpiece of the Soviet space program.

Learning the lessons

For the N1's second launch attempt, engineers chose vehicle No. 5L, which would have to fly with only some of the upgrades recommended in the wake of the first launch failure. A full list of required changes would be implemented later on the No. 4L rocket, which was put aside for now.

At the end of May 1969, the program managers held a series of meetings in Tyuratam with the formal goal of "closing the issues" from the failed launch of the 3L rocket and moving on with the launch of vehicle No. 5L. The first meeting on May 29, which did not include the top brass, was considered a "rehearsal." At the event, Boris Chertok, who was responsible for the flight control system, explained to his superiors that despite all the changes, his team would be unable to prevent the KORD diagnostics network from issuing random commands, if its cables were

damaged by a fire similar to the one that had destroyed the first rocket. The head of the department at the General Machine-building Ministry, Viktor Litvinov, who chaired the "rehearsal," told Chertok "better not to mention this" during the full State Commission meeting next day.

Then, Vladimir Barmin, who was in charge of launch infrastructure for the N1, prophetically asked whether anybody could guarantee that the accident with the first rocket would not replay itself 50 seconds earlier, while the vehicle was still on the pad? In order to preserve the expensive launch facility, Barmin proposed to block the emergency engine cutoff for a preiod from 15 to 20 seconds, so that even an uncontrollable rocket could fly itself into the desert. (A special emergency flight program could be developed to guide the rocket away from the pad, if its nominal flight was no longer possible). Again, after a hot debate, Barmin promised not to raise this issue with officialdom. In turn, Chertok and his colleagues promised to study Barmin's proposal, however they felt they had no time to make such a change for the upcoming launch. (685)

Instead, over the objections of propulsion engineers, Chertok's team decided to disable the KORD's ability to shut down engines based on their pulsation, even though the data from these sensors would still flow to ground control via telemetry channels for post-flight analysis. To prevent possible interference in the KORD, the command-carrying and data transmission lines were better isolated from each other into separate cable bundles and more reliable power generators were installed. To better protect engines from fire, the thermal insulation was reinforced with special asbestos blankets.

In addition, a structural ring holding the propulsion system on the first stage of the rocket was reinforced. It was likely prompted by the telemetry data from the first launch about the acceleration reaching 35G exerted onto this structure, when all 30 engines had suddenly reached their full thrust at liftoff. (706)

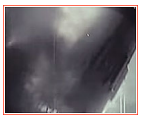
Finally, the number of measuring sensors on each engine was increased to 16. As a result, just the propulsion system of the first stage was expected to relay nearly 500 various parameters to ground control, while the whole rocket was now designed to transmit data from around 10,000 points. It gave an overwhelming amount of test work to telemetry specialists. At the peak of the launch campaign, they had to work multiple eight-hour shifts in a row, taking short naps right in the rocket or at any convenient place around it. Once a group of test officers sat down on an instrument container to discuss where to look for a missing colleague, when the voice from inside the container told them that he was right under them! (233)

Go ahead

On May 30, the State Commission met in the conference room of the main assembly building at Site 112, where the head of TsKBEM design bureau Vasily Mishin made a final presentation on the 3L accident and on the upgrades for the 5L mission. The Minister Sergei Afanasiev insisted

aboard the first stage triggers termination of the flight, while one engine continues firing and causes the rocket to topple. Credit: RKK Energia

The emergency escape system fires to eject the descent vehicle from the failing rocket, as it tumbles to the ground. Credit: RKK Energia



The N1 No. 5L rocket collapses back onto its launch pad seconds after liftoff. Credit: RKK Energia

that Chertok elaborate on how the KORD flight control system had managed to shut down healthy engines on the first N1. Barmin reported on the readiness of the launch pad, but did not mention his earlier demands. The meeting then proceeded smoothly until the status of the next rocket -- 6L -- came up on the agenda. For this launch, Mishin committed to roll out an operational LOK lunar-orbiting spacecraft instead of the makeshift L3S ships flown as payloads on the first two rockets. However, it turned out, nobody had developed procedures for handling the explosion-prone liquid hydrogen which would have to be loaded into the new power-generating fuel cells onboard the LOK. It was required to form a special commission to investigate the matter. Returning to the business at hand, the commission set the launch of the N1 No. 5L rocket for July 3, 1969.

The conflagration after the rocket impacts the ground.

A US reconnaissance satellite imaged the aftermath of the N1 explosion in Tyuratam. Credit: CIA

On June 3, exactly a month before the second launch attempt, top Soviet space officials met again, this time at Korolev's main office at the TsKBEM campus in Podlipki near Moscow. Mishin once again ensured his industry bosses that his team had learned the lessons of the first failure and had taken measures to protect the KORD control system from interference. Thus, the No. 5L vehicle could be confidently sent on a mission to fly around the Moon. Without the advice of his subordinates, Mishin also promised that the next vehicle (6L) would launch a fully equipped LOK spacecraft on a mission around the Moon with a subsequent return to Earth. (In this case, the spacecraft would enter an orbit around the Moon). Mishin claimed that all TsKBEM's systems were ready for flight and that his engineers were just waiting for some deliveries by subcontractors. Deputy Chairman of the State Committee for Defense Industries Leonid Smirnov, who chaired the meeting, questioned whether Mishin was forthcoming about the problems facing such a challenging flight.

Vasily Mishin (left) and Nikolai Kuznetsov next to the NK-33 engine, which was designed for the upgraded version of the N1 rocket. Credit: Progress

As Chertok admitted in his memoirs, he had often contacted Smirnov's deputy Igor Bobyrev asking for his help in putting pressure on various suppliers. During the meeting, Chertok tried to "save" Mishin telling that it would be realistic to manufacture and deliver all systems for the first LOK spacecraft during 1969, however it would then require a series of integrated tests, in particular, to certify new fuel cells, new computers and optical sensors.

The head of Academy of Sciences Mstislav Keldysh then asked whether it was possible to prepare a backup plan for launching 6L and 7L rockets with mockups, if the next launch of the 5L vehicle revealed more problems. Keldysh argued that without a proven rocket, there was no need to burden the team with the task of flying around the Moon, because the parallel L1 project had already been trying to achieve just that (with a smaller Proton rocket). Another official, Georgy Tyulin supported Keldysh and went even further, saying that it would be enough to insert a dummy cargo into the low Earth orbit. However, Mishin argued fiercely against any shortcuts. He promised that the 7L mission would not only enter orbit around the Moon, but also deliver an unmanned version of the LK lander on the lunar surface! This time, his own deputy Konstantin Bushuev said that 6L could only realistically fly with a simplified L3S vehicle and his team could not guarantee a flight around the Moon. Instead, it could enter the Earth orbit and, possibly, fire an engine there to enter a high elliptical orbit. A powerful party official Ivan Serbin demanded to

fulfill the approved plan and warned that any downgrades of the program would have to be reported to the Central Committee. The meeting than decided to let Minister Sergei Afanasiev reevaluate the plan and then to submit the final flight schedule to the Kremlin for approval.

Surprisingly, the next item on the agenda was the discussion of the Martian expedition and the development of a smaller sibling of the N1 rocket based on its three upper stages and designated N11. Obviously, none of these proposals could attract any serious attention from the Soviet officials at the time. Keldysh was the only person among the top brass interested to hear about Mars. Mishin described the Interplanetary Orbital Ship, MOK; Martian Landing Ship, MPK; The Earth Return Ship and a power-supply unit with a nuclear reactor to power electric engines. The spacecraft would use artificial gravity and return to the Earth orbit after a couple of years in flight. According to the mission designers, if the N1 rocket could be upgraded with a more powerful hydrogen upper stages, two such boosters would be enough to support a manned mission to Mars.

Keldysh urged Mishin to continue Mars studies as long as they did not interfere with the ongoing work on the lunar project. However, the smaller N11 rocket was practically unanimously rejected as a duplicate of the already available Proton. Mishin ensured the group that the hydrogen fourth stage for the N1 would be ready for ground tests in a year.

By the end of the meeting, Smirnov asked whether Mishin could provide a flight of three Soyuz spacecraft by the anniversary of the October revolution. Chertok and Bushuev confirmed that such a flight had been on track. To prepare this mission, Chertok had to supervise upgrades to the docking system, which prevented his trip to Tyuratam to witness the launch of the N1 No. 5 rocket.

What had already become a bad tradition, Mishin was also apparently involved in an argument with Air Force officer Nikolai Kamanin on the crew assignments -- this time, over the members of the first Soviet lunar expedition. Chertok later claimed that he and his associates had viewed these "quarrels" as trivial and inappropriate. When the list of candidates was finally approved, Mishin announced that the lunar expedition would be accomplished by the end of 1970. (685)

5L payload and flight plan

Not surprisingly, for the upcoming 5L launch Mishin decided to attempt a circumlunar flight. The L3S payload for the second N1 rocket was assembled from a mix-and-match of hardware borrowed from the L1 project, but according to Chertok also included some available components of the LOK spacecraft and a mass mockup of the LK lander. However, according to most sources, The L3S paylaod included just the 7K-L1A spacecraft with fully operational Block D and Block G space tugs. The rocket also had a functional emergency escape system, apparently, for the first time.

Flight control computers installed inside the descent module of the L1 spacecraft had the task of

sending commands to Block G and Block D, after the entire stack had separated from the third stage of the N1 rocket in the low Earth orbit.

To ensure the rendezvous of the spacecraft with the Moon, the launch time for the N1 No. 5L vehicle was set for June 3, 1969, at 23:18 Moscow Time. (685) (It would be already past midnight local time.) The night time launch was also designed to simplify the evacuation of the launch area, since most servicemen and engineers would finish their day shifts and go home to the safety of Site 10 in Tyuratam. (233)

Rollout to the pad

The N1 No. 5L rocket with the L3S spacecraft was rolled out to the "Right" launch pad at Site 110 on June 20, 1969, according to one source (233) or in May 1969, according to another. (705) At the time, a full-scale mockup of the N1 rocket, known as 1M1, was erected right next to its flight-worthy sibling to conduct autonomous and integrated tests of various systems at the nearly completed "Left" pad at Site 110. (705) Several aerial and ground-based photos preserved this rare historic moment for future generations, capturing two monumental rockets towering over the steppe. Even the American Saturn-5 rocket, which launched Apollo astronauts to the Moon, never had a chance to stage such a duet. For safety reasons, the M1M rocket was returned back to the assembly building shortly before the scheduled launch of the 5L mission.

The fateful launch

Preparations of the N1 No. 5L rocket on the launch pad at Site 110 went without major problems. However instead of the bitter cold of the previous launch campaign, the N1 personnel now endured an unbearable heatwave. Some officers now remembered winter with some nostalgia: "When you are freezing you are not thirsty at all." (685)

After completion of fueling on the eve of the launch, the team led by Vasily Yashkov heard the command on the intercom to "review the vehicle." They went through various access bridges of the gantry checking that all safety pins marked with red ribbons had been properly removed from the rocket.

By the end of the work day on July 3, thousands of personnel members working within the potential explosion radius of the N1 rocket were ordered to evacuate. By 6 o'clock in the evening, hundreds of cars and trucks were clogging the roads in the central section of the test center in the midst of summer heat and dust. They were carrying not only soldiers, officers and engineers, but even banners of military units and anything else considered valuable. To young test officer lieutenant Valery Menshikov the whole scene recalled chronicles documenting great exodus of Soviet citizens in the face of the German onslaught during World War II. Menshikov was responsible for the evacuation of the night shift of a fueling station at Site 112 to the more remote Site 115, where protective trenches had been dug out for the occasion.

Despite the official secrecy, everybody at the test range knew about the impending launch. As the local midnight approached, family members of launch personnel gathered on the outskirts of the residential area at Site 10 to see the N1 fly. Many people stood on the roofs of their apartment blocks for the best view and even yelled to less informed neighbors the status of the countdown!

The N1 No. 5L rocket lifted off as scheduled from the "Right" pad at Site 110 on July 3, 1969, at 23:18:32 Moscow Time (or 23:18:36.524). Telemetry officer Yuri Ivanchenko was sitting at the console inside the assembly building monitoring the combustion chamber pressure of the first stage engines displayed on his screen as animated bars. "We've got preliminary (thrust)...", Ivanchenko yelled into the microphone as drops of sweat were running down his spine. A moment later, bars on screen jumped to the maximum pressure and a chorus of voices responded with "There is main (thrust)".

The giant vehicle rose above the launch pad turning night into day as far as 50 kilometers away. Ivanchenko heard the announcer reporting: "Five seconds -- flight normal, 10 seconds -- flight normal," when suddenly several of his thrust indicators collapsed to zero! "Pressure in engines 1 to 12 is zero," Ivanchenko yelled.

When the rocket climbed to an altitude of around 100 meters just 10.5 seconds after liftoff, some bright pieces fell off from its tail section. The colossus seemingly froze in mid-air and started tilting to the side. At the tip of the rocket, the emergency escape engines fired and carried the top

section into the night. Moments later, the giant rocket with most of its propellant still onboard collapsed back onto the launch pad. (705)

In violation of procedures, Ivanchenko dropped his head set and rushed to the window in the hallway. He saw the fiery mushroom cloud silently rising over the launch pad. Instinctively, he jumped away from the window toward the door and a moment later a loud bang slammed the window open and pieces of glass showered the floor.

At Site 115, apparently the closest point to the launch pad where personnel was allowed to stay, Menshikov and his soldiers and officers needed a few moments to fathom what had just happened. While they stood frozen and stunned, a giant red and black mushroom cloud erupted over the pad and steppe, and air around them started vibrating. "Lay down" Menshikov finally yelled and he jumped into the trench behind him. Soldiers and officers were scrambling into the darkness of the trench, tramping and falling onto each other, suddenly realizing the total inadequacy of this "protection." Above them, the ground was galloping and the air roaring with shock waves. (704)

As Lt. Colonel Semen Komarovsky later said, "Today,... I saw without exaggeration the end of the world, and not in a nightmare but while fully awake and standing right next to it." (706)

In Leninsk, at Site 10 (Tyuratam's residential area) terrified residents saw the ominous glow of the failed launch, followed by a red mushroom cloud and the roar of the explosion. The festive atmosphere momentarily changed into the horror. (705)

The aftermath

As the shockwave and the rain of metal debris subsided, Menshikov and his colleagues all emerged out of their shelter stunned but unhurt. Flames were still raging at the launch pad to the northeast under a starry night. The power was shut off around the entire center but five minutes later most facilities started getting their lights back on. (704)

Top officials were allowed to leave their launch control bunker around 3.5 kilometers from the pad only half an hour after the explosion. When they came up to the surface, a drizzle of unburned kerosene droplets was still coming down to the ground. As was later estimated, as much as 85 percent of the propellant onboard the rocket did not detonate, reducing the force of the blast from a potential 400 tons to just 4.5 - 5 tons. (233) Also fortunately, evacuation measures proved to be effective, as all reports from various sites included "no fatalities." (685) However due to paranoid secrecy, security services apparently intentionally disconnected still operational phone lines between technical facilities and the residential area, leaving numerous family members agonizing for hours over the fate of their loved ones.

In the meantime, test officers and engineers were streaming back from their shelters to their regular work places. Menshikov and his colleagues found their fueling station in total disarray.

Doors and windows were blown off, main gates crooked, equipment thrown all over the floor. Most buildings at Site 113 and surrounding facilities were in similar shape. As dawn came, they were terrified to see numerous dead birds and small animals littering the steppe.

The heaviest damage was obviously at the epicenter of the explosion. The "Right" pad of the N1 rocket at Site 110 was completely wrecked. One of the 180-meter lightning towers collapsed and was twisted into a spiral. (705) Some pieces from the rocket were found as far as 10 kilometers away and a 400-kilogram gas reservoir landed on the roof of the assembly building at Site 112, four kilometers from the pad.

Windows were blown off in buildings at Site 2, located six kilometers from the launch pad and as far as 40 kilometers away. A main display window at the Luna cafe in the main residential area at Site 10, some 35 kilometers from the epicenter, was shattered.

The total damage from the accident was put at 350 thousand rubles, probably a greatly underestimated amount. (704)

The investigation

On the morning after the accident, Ivanchenko received the assignment to lead a platoon of soldiers to the launch pad to recover the closest the N1 had to black boxes -- autonomous registers, ARGs. These devices captured high-frequency engine parameters on multiple cassette tapes. To their surprise, the searchers were able to find a number of cassettes despite the complete chaos at the crash site. Conscripted soldiers were especially delighted, because for each cassette, the head of the 6th Test Directorate Yevgeny Moisseev was rewarding its finder with a trip home, while leading engineer Boris Dorofeev was sweetening the deal further with 50 rubles. The cassettes were jammed and their titanium casings had to be sent to the Tyuratam's main repair depot where they had to be cut with special tools. (233)

Ivanchenko returned home only at the end of the day on July 4, however, his family members had long known his whereabouts from his colleagues, who had their ways of bypassing KGB censors to call his home.

In the following days, analysis of the available telemetry, photos and film recordings revealed that as the propulsion system had been firing with the rocket still on the launch pad, a turbopump supplying liquid oxygen to engine No. 8 exploded a quarter of a second before liftoff. Other engines kept working and the rocket lifted off. It climbed to an altitude of around 200 meters, where engines started shutting down. From 10.5 to 12 seconds into the flight, all engines but No. 18 were cut off by a command from the KORD diagnostics system. (705) The thrust of a single engine on one side of the rocket caused the giant vehicle to tilt as it was collapsing back to the pad. At T+15 seconds, the emergency escape system fired pulling away the unmanned descent module, which later landed safely two kilometers away. (690) At T+23 seconds, the rocket fell sideways on the launch pad, triggering a series of explosions.

Investigators were picking up debris from the blast including engines as far as one kilometer from the pad. They discovered that the turbopump of engine No. 8 had signs of melting and damage from an internal explosion, unlike the other 29 engines. The force of this blast was fatal for the entire rocket. Various arteries leading to other engines were severed. A huge fire likely fed by the severed propellant lines started the immediate destruction of the lower portion of the first stage. Still, Chertok admitted that, at the last moment, the KORD system registered out-of-limit parameters on pressure and turbopump rotation rates in engines No. 7, 19, 20 and 21 and cut off all these engines. The telemetry did not reveal how or why other engines had been shut down. Investigators apparently could never establish why engine No. 18 continued firing in the midst of total pandemonium.

Under pressure to find a culprit in the initial explosion, propulsion engineers at the Kuznetsov design bureau insisted that some foreign object must have entered the pump. They hypothesized that a steel diaphragm from a pulsation pressure sensor could have been torn off and ingested into the oxidizer pump. The evaluation of the sensor and various experiments trying to simulate this scenario brought inconclusive results. No other candidates for a "foreign object" in the pump could be identified.

Any suggestion that the pump could explode all by itself was politically unacceptable, since it would stall the entire Soviet lunar program. Chertok quoted a theory first put forward by TsKBEM engineer Ivan Raykov according to which a very slight shift of the pump's rotor off its rotation axis could cause its blades to scrape the static part of the pump and produce sparks. In the presence of liquid oxygen, it would lead to an immediate explosion. Again, it was impossible to prove or disprove such a scenario. Therefore, from then on, a "foreign object" became a favorite excuse for engine failures for the lack of better explanations.

Mishin did not attempt to blame the engine designer Nikolai Kuznetsov for the disaster, since they had both signed off on the decision of an interagency commission that certified the engines for flight tests back in 1967. However, when Ustinov reportedly asked Kuznetsov's main rival Valentin Glushko about possible culprits, he responded that he would never believe in "supernatural forces throwing foreign objects into pumps." (685)

Behind the Iron Curtain

Unlike the first N1 flight completely missed by the US intelligence, the second launch or rather its disastrous aftermath was clearly captured on film by CIA's spy satellites. (693)

The fallout

In the midst of hot discussions inside the investigation commission, news reached the USSR about the launch of Apollo-11 on July 16, 1969. Four days later, the Moon Race was over for the USSR in the political sense. However, it would do little to shake the enthusiasm of thousands of Soviet engineers for the exploration of the Moon and for other ambitious projects, which would

be possible with the introduction of the N1 rocket.

During one of the meeting discussing the matter, optimists tried to find a silver lining in the situation, first of all in the fact that there were no casualties in the accident. To that, Vladimir Barmin angrily said that he and hundreds of his workers had been "casualties," because they would now have to essentially rebuild the facility. Barmin estimated the damage not in rubles, which nobody counted at the time, but in precious time for the space program. It would take at least a year to restore the facility even with the most expeditious work, Barmin predicted.

To the comment that flight tests could resume immediately from the undamaged "Left" pad, Barmin said that he would never again give permission to launch until the rocket had been modified to block the engine cutoff over the launch pad. "Take it into the steppe and blow it up there," Barmin said. "You can make many rockets but the pad is the only one, and even that one is yet to be finished." (685) Again, his words were prophetic.

*Next mission of the Moon Race: **Zond-7***

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