# THE SOVIET MANNED LUNAR PROGRAM

EDITED & COMPILED

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ABSTRACT



***Twenty years after the first American moon landing, on August 18, 1989 the USSR officially acknowledged the existence of their manned lunar program with an initial release of information by the Soviet newspaper Izvestija. An increasing number of photographs and blueprints of Soviet lunar hardware have become available to Western analysts and space observers. It is now clear that personal rivalries, shifting political alliances and bureaucratic inefficiencies bred failure and delays within the moon program. There was strong competition between research teams and laboratories. This internal competition and the low budget for manned exploration of the Moon explains the failure of Soviet technology against the successful American Apollo program.***

***This paper summarizes the Soviet manned lunar program in the light of the latest findings published in the West.***

## RED STAR IN ORBIT

Soviet capability in space became clear to the world in October 1957, when the Soviet Union launched Sputnik 1, the first artificial satellite. The effect it produced in the United States varied between shock and panic. A month later, the Soviets launched Sputnik 2 - a much heavier satellite carrying a dog, Laika. Subsequent surveys revealed that within months nearly all Americans had heard of Sputnik. Press reaction discussed the Soviet satellites in terms of American prestige, and its scientific and military reputation being at stake. Watching for Sputnik was a world-wide event, and newspapers gave predictions on its passes.

Two years later, the Soviets extended their early lead in space by launching probes that hit the Moon (Luna 2) and returned the historic first photograph of the far side of the Moon (Luna 3). Meanwhile, the unfortunate Americans failed to launch far smaller satellites (Vanguard 1 in December 1957) and lunar probes (Pioneer 1-4) during 1958-60. But on 31 January 1958, the US Army finally managed to launch the first American satellite - a small 15kg cylinder named Explorer 1. Since all the early satellites and lunar probes were launched on converted intercontinental ballistic missiles, the Soviet advantage underlined fears in the US that a "missile gap" existed between it and its Cold War enemy, an issue that Kennedy exploited to his advantage in the 1960 presidential campaign.

## FIRST MAN IN SPACE

At first, the shape that a US-Soviet space race would take was unclear. If President Dwight D. Eisenhower had had his way, there might never have been one at all. He consistently refused to approve space programs justified on purely political grounds, such as a $38 million manned circumlunar mission proposed in December 1960. But Eisenhower did set up a civilian space agency to plan ahead - the National Aeronautics and Space Administration (NASA), which was inaugurated on 1 October 1958. Within seven days, NASA announced a man-in-space program called Project Mercury.

Politics affected the issue early in 1961, when John F.Kennedy became president. On 12 April 1961, Yuri Gagarin orbited the Earth in a Vostok spacecraft, Once again, the Soviets had beaten the Americans. Spurred on by this setback (and by the Bay of Pigs fiasco five days later), President Kennedy had the necessary base for a national commitment and, on 25 May 1961, sent to Congress the message 'that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the Moon and returning him safely to the Earth.'

**THE RACE BEGINS**

Meanwhile, behind the scenes in the USSR, ***Sergei Korolev*** was busy preparing a response to the American challenge. Korolev was the top-secret "Chief Designer" who had developed the world's first intercontinental ballistic missile, the R-7 or "Zemyorka" (Little Seven). This rocket made a poor ICBM but an excellent launch vehicle; the R-7 had been used for all Soviet space launches to that point. Korolev was also a visionary and an excellent manager who had created & supervised most of the programs responsible for developing the rocket's payloads - Sputnik, Luna, Venera... His latest masterpiece, Gagarin's Vostok spacecraft, had been developed as a spy satellite but could also serve as a manned spacecraft.

Unlike the Americans, the Soviet space program had no centralized organization or long-term plan. Korolev realized early on, in 1959, that the growing diversification of the space program would require a major reform of its organizational structure. Unfortunately for the Soviet space effort, Soviet premier Nikita Khrushchev ignored Korolev's proposal for reorganization and the space program remained in the hands of mostly non-specialized design bureaus, many of them working for different ministeries. Although Korolev subsequently delegated most of the work on unmanned spacecraft to his associates, overseeing so many projects must have placed a tremendous burden on him and may have slowed many of them down (Hendrickx, 1996).

**DESIGNERS FALL OUT**

Korolev was not the only designer of rockets and spacecraft, however. ***Vladimir N. Chelomei*** had developed military missiles but had no experience with space launchers. On the other hand, Chelomei had hired Khrushchev's son, Sergei. That family link offered a great advantage in a political system where personal connections were often all-important. With Khrushchev's blessing, he soon had the biggest project budget of all bureaus in the USSR. Chelomei OKB-52 had ambitions to expand his works into what had been Korolev's work (Harvey, 1996). In the USSR rival design bureaus not only designed but built hardware. Decisions about which craft would fly were taken much later by the Soviet leadership, based on recommendations from the Soviet academy of sciences led by Mstislav Keldysh. As a result, the Soviet space program contained several rival, parallel projects. This presented a roadblock to establishing a single coordinated plan for reaching the Moon.

Chelomei soon got an extremely important ally when ***Valentin Glushko***, the primary designer of Soviet rocket engines, allied his Gas Dynamics Laboratory with OKB-52 following a strong disagreement with Korolev. Disputes between Glushko and Korolev dated to the 1930s, when Glushko's testimony helped to send Korolev to a forced-labor camp (Logsdon,1994). The two men clashed over the new rocket engines for the next generation of Soviet launchers, but the conflict was also a question of authority. Korolev had been a former deputy of Glushko's before becoming chief designer, and both men collaborated on the R-7 project in the 1950s. Korolev wanted to use new high-energy cryogenic fuels such as liquid hydrogen. Glushko refused, preferring to design an engine fueled by storable but but highly toxic hypergolic chemicals that ignite on contact (Mishin, 1990). His new highly efficient RD-253 rocket engine was quickly adopted for use by Chelomei, who proposed a series of "Universal Rockets" (Universalskaya Raketa - U.R.) derived from one of his designs for a giant intercontinental ballistic missile - the UR-500 Proton (Logsdon, 1994). The go-ahead for this program was given on 29 April 1962 with the initial goal being a 3-stage space launcher called UR-500K. This was created simply by taking the UR-500 ICBM first stage and putting a small two-stage UR-200 rocket on top of it (Hendrickx, 1997). In 1962 Khrushchev also assigned Chelomei's group to prepare for a manned spacecraft intended for circumlunar flight - the LK-1. At this time there was no stated goal of a Moon landing (Mishin,1990).

**PROBLEMS WITH THE N1**

Meanwhile, Korolev was busy working on his own carrier rocket proposal - the N-series (Nositel="Carrier"). A

government resolution issued on 23 July 1960 called for a family of rockets to launch payloads ranging from heavy civilian & military satellites to heavy unmanned & manned spacecraft to the Moon, Venus and Mars (Hendrickx, 1996). Late in 1961, Korolev's team was asked to develop the N1, which would insert a 40-50t into low Earth orbit with a development time frame from 1962 to 1965. A larger version called N2 would launch heavier payloads in the 60-80t range, with a development period from 1963 to 1970. However, work on the N-rockets were limited to a conceptual design only when Chelomei's LK-1 became the primary manned lunar program in late 1961 (Mishin 1990, Landis 1992).

Later, Nikita Khrushchev wanted a larger uprated version capable of launching a 75t military space station called "Zvezda" or OS-1, armed with nuclear weapons! The go-ahead for an uprated N1 carrier rocket was given on 24 September 1962 with flight tests to begin in 1965 provided the necessary launch site was in service by that time. No other N1 payloads were authorized at this stage although Korolev probably had both Earth orbit as well as lunar / interplanetary uses in mind when the OS-1 was under consideration (Vick, 1994).

Korolev's falling-out with Glushko meant he had to find an alternative source of rocket engines. He turned to Nikolai D. Kuznetsov, who had developed and built only aircraft engines in the past such as those used in the Tupolev Tu-144 supersonic transport. Kuznetsov's group had to begin its work on rocket propulsion systems basically from scratch. In the limited time available, Kuznetsov was able to develop only a conventionally fueled engine of rather little power. The final N1 version needed no fewer than 30 such engines in its first stage to achieve sufficient power for a lunar mission (Harvey, 1996).

**THE SOYUZ SPACECRAFT**

Korolev's third cornerstone project (after the N1 heavy-lift/multipurpose rocket and OS-1 space station) in his man-in-space program was a new, advanced multipurpose spacecraft called 7K SOYUZ ("Union"). The older Vostok manned spacecraft was rather limited since it could not change orbits in space, rendezvous and dock with other spacecraft. Its lone cosmonaut was only a passenger, and the spherical descent capsule would have been unsuitable for lunar missions due to high G-forces during atmospheric reentry.

Although the future course of the Soviet space program was unclear when the Soyuz was conceived in 1959-62 (space stations, lunar missions or even a manned flight around Mars were considered), it was generally agreed on that rendezvous & docking would play a major role. So this requirement was part of the design right from the start. Like the US Apollo CSM, the new spacecraft (initially called "Sever" or South) would also be capable of flying around the Moon (Feoktistov, 1996). On 10 March 1962, actual work got underway when Korolev approved a document entitled 'Complex for the assembly of space vehicles in artificial satellite orbit (the Soyuz)'. This described a 3-man spacecraft that would dock in orbit with a stack of five separately launched solid rocket motors to boost 7K to the Moon, but other leading OKB-1 engineers convinced him this approach was not the right one. Korolev then turned to another system consisting of one manned spacecraft (Soyuz-A), a translunar injection stage containing automatic rendezvous and docking equipment (Soyuz-B) and three tanker spacecraft (Soyuz-V). The latter would refuel the Soyuz-B, which would dock with Soyuz-A, sending it on a circumlunar flyby. Initially, the "Soyuz complex" would allow the Soyuz to maneuver to high orbits and refuel the OS-1 space station. This plan was approved on May 10 1963 by Korolev, who already had experimented with launching two manned spacecraft at the same time during the Vostok 3,4 mission half a year earlier (Harvey, 1996). He also had plans for a manned lunar-landing craft that would have ferried cosmonauts between the lunar surface and a Soyuz craft in orbit around the Moon. But the Soviet leaders rejected both plans and continued to support Chelomei's LK-1 project.

**NEW LEADERS, NEW LUNAR PLANS**

After the Vostok 5,6 flight in June 1963 the Soviet manned space program appeared to lay dormant to Western observers. But behind the scenes, Korolev was busy designing the N1 rocket, OS-1 space station (a full-scale 18.5m high mockup was constructed) and the Soyuz spacecraft that would transport cosmonauts to it. A new series of unmanned Luna probes attempting a soft landing on the Moon had been launched since January 1963, but so far without success. He also continued to lobby hard for a manned circumlunar mission, this time consisting of a Soyuz launched by a smaller N11 rocket (=N1 without the first stage). This too was rejected, but on 3 August 1964, the Central Committee finally passed a resolution (no. 655/268 'On work involving the study of the Moon and outer

space') to put a single cosmonaut on the Moon in 1967-68 before the US Apollo flights. More than three years had passed since President Kennedy's speech. On 3 August the Chelomei bureau also received final approval to build the LK-1 spacecraft to send two cosnomauts on a circumlunar mission by October 1967, the 50th anniversary of the Bolshevik Revolution. At last, the Soviet effort appeared to gain momentum (Harvey,1996).

While all this was taking place, Korolev hurriedly designed a manned 'stopgap' program called Voskhod ('Sunrise') to satisfy Khrushchev's apetite for new space spectaculars. First proposed in February 1964 (Hedrickx, 1997), Voskhod was basically a Vostok capable of carrying 2-3 cosmonauts into low Earth orbit to practise long duration spaceflight or (using additional equipment) spacewalks and dockings in space before Soyuz became available in 1966. But in order to accomodate more cosmonauts, Vostok's single ejection seat had to be removed, leaving the crew with no chance of survival if the R7 carrier rocket malfunctioned during the first 27 seconds of launch until the upper stage could fire (Harvey, 1996). Despite the huge risks, Voskhod 1 took off on 12 October 1964 with three cosmonauts on board - then a new record. Khrushchev was removed from power by the Politburo later that day. The new leadership, headed by Leonid Brezhnev, was less interested in manned space 'firsts' than Khrushchev had been.

By late 1964, three design bureaus had submitted proposals for a manned landing on the Moon. Chelomei's OKB-52 proposed a lunar landing spaceship based on the LK-1 circumlunar spacecraft. It would be equipped with a new high-energy deceleration rocket stage plus landing gear and could land two cosmonauts on the Moon with no need for rendezvous in Earth or lunar orbit. Chelomei claimed this would be simpler and quicker than assembling a vehicle in space like the Americans (and Korolev-) were proposing. The drawback was that his LK-700 spacecraft would have to be rather heavy since it would have to carry additional fuel plus landing equipment for the return to Earth. A large heavy-lift version of the Proton, called UR-700, would be required to launch the spacecraft. Chelomei had been working on this rocket since 1962 (Newkirk, 1992) and now proposed it as a more powerful alternative to the N1. Modular blocks from the Proton program would have been used to assemble a rocket as powerful as the American Saturn V, with a lifting capability of 130 tonnes to low Earth orbit (Clark, 1992).

Mikhail Yangel's OKB-5 design bureau in Ukraine proposed a project called the R-56. It would have used a cluster of at least four long, pencil-like first stages & second stages to create a heavy-lift lunar booster. It would have used the same Glushko-produced engines as Chelomei's proposal, including the giant 7000kN thrust RD-270 which was as powerful as the American F-1 engine used on the Saturn V first stage. Little is known of Yangel's proposal, but it does not appear to have been a serious contender despite being a paper study since April 1962 -originally as a manned circumlunar flight (Harvey, 1996).

Finally, on Christmas Day in 1964, OKB-1 proposed a vehicle based on the N1 launch vehicle -its maximum payload weight now uprated to 92t from 75t- plus two modified Soyuz spacecraft. Korolev's deputy Vasili Mishin suggested that the Soviets use the same 'lunar orbit rendezvous' (LOR) technique as the Americans (Feoktistov, 1994). To save weight, the heavy Soyuz mothercraft (carrying fuel, parachutes and a heatshield for the return to Earth) would be left in lunar orbit while a small 1-man lander would descend to the lunar surface. The total weight of their L3 spacecraft complex would be only two-thirds of the LK-700's. But other OKB-1 engineers were not convinced, noting that the L3 already was dangerously close to the N1's maximum capability. One of the engineers described the program as being 'on the edge of science fiction'. 26 engines had to be installed on the first stage, causing serious reliability problems. Despite this, Korolev turned down a proposal to build a test stand for the N1 - a decision that would later come back to haunt the Soviets. Korolev, now suffering from serious health problems such as hearing loss and a heart condition, gradually became more isolated from his former allies (Hendrickx,1996).

## THE SOVIET LUNAR PROGRAM TAKES SHAPE

The Soviet Union continued to stay ahead of the US in the space race when, on 18 March 1965, Alexei Leonov became the first man to venture outside his Voskhod 2 cabin and perform a 'spacewalk'. Leonov's spacesuit was a prototype for the eventual 'moonsuit' and took place many months before the Americans were ready to attempt a similar mission. But the mission was fraught with danger and Voskhod was to be the last Soviet manned flight for almost two years.

Meanwhile, the Soviet Union had finally made preliminary decisions how it would send men to the Moon:

a) MANNED LUNAR LANDING PROGRAM.
Korolev's/Mishin's proposal was recommended by the Soviet Academy of Sciences, but Mikhail Yangel's design bureau would design the propulsion systems of the L3 craft. The other main contender, the UR-700/LK-700 project, did not receive funding. In May 1965, the Soviet government created the Ministry of General Machine Building to oversee the nation's space program. The goal was now a first manned landing in 1968, and 22 new cosmonauts were recruited in October 1965 to fly the Soyuz and L3 spacecraft (Harvey, 1996).

The L3 mission plan called for the development of two spacecraft that would form the L3 Complex. A lunar orbiting spacecraft named LOK (Lunniy Orbitalniy Korabl) would serve as the mothership during the trip to lunar orbit. One cosmonaut would then perform a spacewalk and transfer to a small LK "lunar cabin" (Lunniy Kabina) which would descend to the lunar surface. It would also be used to return the moonwalking cosmonaut to his waiting comrade aboard LOK in lunar orbit. Having docked, the LK pilot would transfer to LOK, the empty LK would be jettisoned and the two cosmonauts fire the LOK's engine to accelerate out of lunar orbit, returning to Earth three days later. In order to increase safety it was decided early on to launch an unmanned N1/L3 precursor mission to the proposed site of the first manned landing, leaving a backup LK on the lunar surface in case the moonwalking cosmonaut's own vehicle suffered damage during landing. The first Soviet moon landing would thus consist of two launches - one unmanned precursor flight and one manned mission to the same site (Hendrickx,1995).

b) MANNED CIRCUMLUNAR PROGRAM.
Here the picture is less clear. Chelomei only began construction of the LK-1 in early 1965 (Pesavento,1994) and it appears as if there were technical problems attributed to OKB-52's lack of experience with manned spacecraft (Johnson, 1994). The Chelomei bureau fell from favor after Khrushchev was removed from power (Logsdon, 1994), and its contract for the circumlunar spacecraft was cancelled sometime in 1965 (Lebedev,1993), despite reports that ten LK-1 capsules were under construction by September of that year (Pesavento,1994). Korolev's opposition to the LK-1 apparently played a crucial part when the Soviet leaders decided to suspend the project in August 1965 (apparently against the recommendations of several subcommittees). Work on the LK-1 was finally terminated on 27 April 1966 and none of the scheduled 12 unmanned and 10 manned flights ever took place. The Proton ICBM was also cancelled and the UR-500K launcher version almost suffered the same fate (Hendrickx,1997).

Korolev argued that the circumlunar spacecraft should test the same systems and launchers as the primary lunar-landing program, to save time and money. The Soyuz could be adapted for this, and Korolev's proposal to replace the LK-1 was accepted. Chelomei's UR-500K was however retained because Korolev's alternative proposal for a medium capability circumlunar booster ("N2" -- a scaled down version of the N1 without the large first stage) would not be ready in time to support a 1967 circumlunar flight (Hendrickx,1997). It appears that Korolev and Chelomei were ordered to design a new circumlunar mission in late 1965, and that the two chief designers agreed on the basic configuration of the new L1 project in September 1965. The plan would use the Chelomei's UR-500K booster, supplemented by a Korolev upper stage (Block-D) being developed for the N1 rocket and a stripped-down version of the Soyuz spacecraft (7K-L1). Korolev did not manage to wrest away control of the circumlunar project until 25 December 1965 (Logsdon,1994).

c) UNMANNED SPACEPROBES TO THE MOON.
The existing Luna E-6 soft-landing probes had encountered serious development problems and Korolev had to intervene personally to save the project from cancellation when Luna 8 became the eight straight failure of the series on 3 December 1965. Luna 8 was the first lunar probe constructed in the workshops of the Babakin OKB, which had been formed in 1965 to manage the robotic lunar program when Korolev was too busy overseeing it (Hendrickx,1996).

In May 1965 Babakin was also ordered to develop a new generation of heavy spaceprobes called Ye-8 utilizing the UR-500K Proton/Block-D booster. Like the L1, the Ye-8s were originally to be launched on the scaled down N1 rocket described previously, but this plan was cancelled in late 1965 when it became clear that the new N2 would not be ready in time (Hendrickx,1997). The main payload was a remote-controlled lunar rover that would be used to reconnoitre the landing sites of both the backup and prime lunar landers one month before the manned L3 craft was launched. The rover would also carry landing beacons to guide the LK craft during landing. As if that was not enough, the Ye-8 rover was also to be outfitted with oxygen tanks and a small platform for the cosmonaut,

transporting him from his own (damaged-) LK lander to the backup craft if necessary!

Finally a simplified version called Ye-8LS would be created by removing the landing gear and wheels from the Ye-8 descent module/rover vehicle. It would orbit the Moon and photograph the candidate landing sites before the Ye-8s or LKs arrived on the scene (Hendrickx,1995). Before this, a modified version of the older E-6 probe would be outfitted with cameras and perform similar activities from lunar orbit in 1966-68.

**KOROLEV DIES**

Just as the Soviet effort was picking up speed, disaster struck. On 14 January 1966 Korolev died unexpectedly during surgery, robbing the Soviet space program of its main driving force. Korolev was succeeded by Vasili Mishin, who had worked alongside him since 1945. But Mishin was not confirmed in his position until May 1967. An able designer, he had neither Korolev's ability to lead nor his political standing. Continuing struggles with various government ministeries and rival design bureaus slowed progress. Chelomei and Glushko continued to push the UR-700/LK-700 project, formally proposing it again on 16 November 1966 when a 'Commission of Experts' led by Mstislav Keldysh reviewed the progress of the lunar program (Harvey,1996). But the L3 was approved, although its N1 rocket again had proved insufficiently powerful, so more time was lost in yet another redesign which increased its payload mass to 98 tonnes. Four more 1st stage engines were added, increasing the total to 30.

The Soviets still managed to score two more impressive 'firsts' before the American moon program finally moved ahead in 1967. Two weeks after Korolev's death, Luna 9 finally became the first spacecraft to manage a soft landing on the Moon. Eight pictures were transmitted back before the batteries became exhausted on 6 February. Once again, America's equivalent project called Surveyor had managed to get itself two years behind schedule.

Two months later, Luna 10 became the first artificial lunar satellite when it swung around the Moon on 2 April. The probe (a modified E-6 with an added Kosmos particle fields satellite) was really a stopgap solution to prevent the far more advanced American Lunar Orbiter from getting there first. It carried no cameras but did broadcast the 'Internationale' to cheering Communist Party delegates in Moscow, who had assembled for the first congress under Brezhnev's leadership.

Slowly but surely, the Americans were catching up. Despite increased opposition in Congress and the Vietnam War, NASA spent a record $2,967 million on the Apollo project in 1966 - far more than the Soviets could afford to. The giant Saturn V rocket, its multibillion launch facilities and supporting infrastructure were ready for ground-based tests in May 1966. The Surveyor and Lunar Orbiter probes may have been second to the Moon, but they were far more advanced than the Soviet Lunas and quickly completed ten successful missions to the Moon in fifteen months. In manned spaceflight, the Gemini spacecraft (a two-man precursor to Apollo) had been a splendid success. Gemini 8 achieved the crucial first space docking in March 1966. The last for Geminis were put up only two months apart, practising long duration spaceflight, dockings and spacewalks.

The Soviets had to scramble to keep pace. A third two-week Voskhod flight was delayed for two months, then cancelled in within weeks of its planned liftoff in May 1966. The rest of the program was cancelled to save time and prepare for the first flight of new the Soyuz spacecraft (Harvey,1996). It also appears as if the giant OS-1 military space station - suspended since Khrushchev's fall from power two years earlier - was terminated the same year (Vick,1994), to be replaced by a much smaller Proton-launched version called Almaz. Chelomei was now in charge of the project and the LK-1 capsules would form part of the new space station instead, but he continued to propose his alternative Moon plans. In 1967 he began work on engineering mock-ups of the UR-700 engine bays and interstage areas (Vick,1996), challenging Mishin's authority as the leader of the lunar program.

**DISASTER STRIKES**

The crucial centrepiece of the Soviet space program was now clearly the Soyuz spacecraft. Like its American Apollo counterpart, it was far more advanced than anything attempted before. It could change orbits and dock with other spacecraft. It could fly missions lasting several weeks, and variants of it would be used to fly around the Moon (the L1) and to be the mother craft for the manned lunar lander (LOK). The basic Soyuz would be launched on the old R7 rocket and practise rendezvous techniques in Earth orbit. Like Apollo, it suffered serious

development problems and was behind schedule. The first three unmanned test missions all failed in November 1966-February 1967. But the Soviets could not afford to wait. Leonid Brezhnev demanded a first flight in April involving Soyuz 1 and 2, to test the new lunar spacesuits during a 'spacewalk' as well as perform the first-ever docking between two Soviet spacecraft. Both feats would be absolutely essential for the L3 program as well.

Soyuz 1, with Voskhod veteran cosmonaut Vladimir Komarov on board, blasted off on 15 April. An atmosphere of pessimism prevailed at the cosmodrome since a record 203 faults in Soyuz had been detected during the final tests. The Soyuz 1 flight was plagued by serious problems too, and Komarov was commanded back after just one day, and the launch of Soyuz 2 (carrying three more cosmonauts) was quickly cancelled. Komarov's spacecraft (tumbling wildly after one solar panel failed to deploy) miraculously survived the atmospheric re-entry but then the landing parachutes failed to deploy and the capsule impacted at 600km/h. Komarov was buried in the Kremlin wall two days later. The accident set the Soyuz program back two years (Harvey,1996).

**THE L1 PROGRAM BEGINS**

Meanwhile the L1 circumlunar version of Soyuz was also ready for flight, a full-scale version of the four-stage UR-500K rocket and spacecraft had been tested on the pad at Baikonur Cosmodrome in January 1967. The chief designer of the L1 spacecraft was Yuri Semyonov -currently the General Director of OKB-1/NPO Energia (Pirard,1993). In December 1966 the official schedule called for four unmanned tests in early 1967 followed by the first manned circumlunar flight in June 1967 (Hendrickx,1995). At least fifteen L1s had been constructed but only two of them were designed to carry humans, the rest carrying various experiments and biological samples to lunar distance. This suggests that the few planned manned missions were mostly for propaganda purposes. The main internal goal was to serve as a technology testbed, testing hardware (communications, navigation, descent systems etc.) that would be required later on, to land men on the Moon.

The UR-500 Proton had flown only four times before as a two stage booster -essentially the original ICBM configuration- and there were doubts about its reliability, so the Soviets planned to launch the L1 unmanned and send up its two-man crew on a Soyuz spacecraft instead. Both spacecraft would have docked in Earth orbit, and the crew would have spacewalked to the L1. The Soyuz would return to Earth unmanned while the L1 blasted toward the Moon. After two partly successful unmanned L1 launches in March and April the Soviets decided to abandon this plan, however (Hendrickx,1995).

The Soyuz accident appears to have delayed the L1 program as well and tests did not resume until September and November 1967. Neither spacecraft reached orbit due to problems with the UR-500K booster, however, and the original goal of a manned circumlunar flight to comemorate the 50th anniversary of the Bolshevik Revolution had to be abandoned. The best they could manage was an unmanned repeat of the aborted Soyuz 1/2 mission on 27 October, when ground controllers guided the Soyuz test vehicles Cosmos 186 and Cosmos 188 to a perfect docking (another unmanned Soyuz docking test was performed in April 1968). The Soviets pressed ahead and devoted most of their attention to the L1 project in 1967 and 1968, knowing full well that the Americans probably would achieve the first lunar landing. But a manned circumlunar flight before the Americans would steal at least some of Apollo's thunder (Harvey,1996).

**THE COSMONAUTS MISS THE MOON**

The L1 project became known to the world in March 1968 when a 7K-L1 craft (called "Zond-4" by the Soviets to conceal its true purpose) was placed into a highly elliptical orbit 180 degrees away from the Moon. Zond-4 had to be destroyed when a technical error shifted the landing point into the Gulf of Guinea. A new attempt in April did not even make it to Earth orbit and on 15 July 1968, another L1 launch had to be cancelled when engineers overpressurized the 4th stage oxidizer tank during testing. The resulting explosion killed three pad workers. Such accidents became increasingly common in 1967-69, undoubtedly because overworked engineers were under great pressure to catch up with the Americans again. But the cosmonauts training for L1 flights still wanted to fly. They felt that engineers would take greater care in the testing of equipment for a crewed mission (Pesavento,1993).

Meanwhile in the United States, NASA had successfully managed to overcome a severe crisis when astronauts Grissom, White and Chaffee were killed during testing of the new Apollo spacecraft on 27 January 1967. The new

redesigned spacecraft and its giant Saturn V carrier rocket were now ready for manned flight. On 19 August, NASA chocked the Russians by announcing a revised Apollo schedule that included a manned flight to lunar orbit in December 1968, provided the spacecraft's forthcoming maiden flight (Apollo 7) in Earth orbit was successful. Mishin & co. must have thought the Americans to be out of their minds to man-rate a spacecraft for a Moon flight on only its second mission. The Soviet goal was now two completely successful unmanned L1 tests, followed by a manned circumlunar flight in January 1969 at the earliest. Now they had little choice but to move the manned Zond-7 mission to December 1968 instead.

The space race was finally decided in the autumn on 1968. First out of the gate was the unmanned Zond-5 in September. It became the first L1 craft to actually fly around the Moon and caused a sensation in the West when Jordell Bank Observatory picked up a human voice from it! But it was only a tape-recorded experiment to test the communications system. The mission generally went well, although an operator error forced a landing in the Indian Ocean. A ship from the Soviet Navy picked up the capsule the next day and returned it to the USSR. The biological experiments contained on board (turtles and banana flies) had survived. The relieved Russians released information to the West which confirmed NASA's worst fears:'Zond flights are launched for testing and development of an automatic version of a manned lunar spaceship . . .'

The Americans struck back on 11 October, when Walter Schirra, Donn Eisele and Walter Cunningham put the new Apollo 7 through its paces during an 11-day mission in Earth orbit. The mission generally went well and Apollo 8 soon received the final go-ahead for a circumlunar mission. But only a day later the Soviets responded by flying their first manned Soyuz flight since the Komarov accident, when Soyuz 3 (with cosmonaut Georgi Beregovoi on board) practised docking maneuvers with the unmanned Soyuz 2.

Everything now depended on the Zond-6 flight in November. If it was a complete success there was still a small chance that the next flight in December would be manned. The probe was launched safely on 10 November and flew past the Moon three days later, but the landing maneuver went totally wrong. First the spacecraft depressurized because of a faulty rubber gasket a few hours before reentry, killing all animals on board. The capsule descended safely through the atmosphere but then parachute deployment came too early and it crashed on Soviet soil. But the Soviets did not reveal the failure for propaganda reasons, instead saying the mission had been a complete success (Harvey,1996). Consequently NASA was fearing the worst while preparing the Apollo 8 vehicle in December. Due to the pecularities of celestial mechanics the Soviets would have been able to launch a lunar spacecraft two weeks before the 'launch window' opened in the US. The L1 cosmonauts did send a letter to the Politburo asking for permission to launch a manned mission. They even travelled to the Baikonur Cosmodrome in order to be ready to fly at a short notice. But the order never came and two weeks later, Apollo 8 astronauts Frank Borman, Jim Lovell and Bill Anders became the first men to fly around the Moon (Pesavento,1993).

**THE L1 PROGRAM TAPERS OFF**

The L1 naturally ceased to be a high priority program after the successful Apollo 8 flight and all manned flight were put on hold. It was instead decided to fly a few more test missions in 1969-70. A probe launched in January 1969 failed to reach orbit because of problems with the UR-500 carrier. In August, Zond 7 became the only completely successful L1 mission, passing the Moon at a distance of 1500km before safely landing in the USSR. Three months later, one of the two man-rated L1s was launched on an unmanned test flight to test the Block-D systems in Earth orbit, but the launch ended in yet another failure (Clark,1997). A second circumlunar test in December followed by a manned voyage for Lenin's birthday celebration in April 1970 with the single remaining crew-rated L1 was briefly considered but never approved -- possibly because the program was delayed yet again (Hendrickx, 1997). Instead, the Soviets launched a final unmanned test in October 1970, but the mission was only a partial success. Zond 8 ended the lunar flyby program by making an unplanned ballistic reentry into the Indian Ocean after an attitude control sensor failed. The final L1 capsule (equipped for manned flight) was then launched unmanned as Cosmos 382 in December 1970, successfully testing the Block-D stage in Earth orbit (Clark,1997).

**PREPARING FOR THE FIRST MANNED LUNAR LANDING**

As the L1 program was winding down in early 1969, the focus shifted to the N1 program. The first flight-ready N1 carrier rocket had been installed on the newly constructed launch pad as early as 7 May 1968, but had to be returned

for repair when cracks (possibly caused during installation of the payload) were found in the first stage. It was rolled out again in the mid-January 1969 after a brief test period on the pad in November 1968 (Lebedev, 1992).

The N1 rocket's path had been a long and difficult one. Mishin had to wait until 4 February 1967 for the government to commit significant resources to the project. A new resolution ('About the course of work in the creation of the UR-500K-L1') specified test flights in September 1967 and a first manned lunar landing in 1968. The latter was upgraded to 'an objective of national significance', and initial assembly of the first N1 boosters were started at the Baikonur Cosmodrome in late February (Harvey,1996). Work on two launch pads 500 meters apart was also completed, and in November an N1 mockup was placed on pad 1 for three weeks of tests, checks & ground crew training. It was returned to the assembly building in mid-December (Lebedev, 1992).

In March 1968, the cosmonauts started training in preparation for a Moon landing at Star City, Moscow. A moonwalk simulator was installed in the gymnasium, and the cosmonauts practised lunar landings with a modified version of the Mi-8 helicopter (Pirard,1993). But they still had no L3 spacecraft to fly a year later - the constant Soyuz and L1 troubles in 1967-68 apparently had prevented the Soviet engineers from devoting their attention to the manned lunar-landing spacecraft. Consequently it was decided on 1 January 1969 to test the N1 by launching an unmanned L1 craft, to perform high-resolution photography of potential landing sites from lunar orbit. The L3 spacecraft (LOK and LK) would be tested later, for a first landing in 1970-71. The first lunar-landing mission would be commanded by the Voskhod 2 veteran, Alexei Leonov, with Oleg Makarov serving as the LOK pilot in lunar orbit.

**NEW OBJECTIVES**

Although the Soviets were still hoping that an unplanned setback might delay the Apollo program long enough to permit a Soviet cosmonaut to get to the Moon first, they were forced to prepare for the worst after Apollo 8. The Babakin bureau had completed work on the new third generation Ye Luna series (the older E-6 probes had performed three missions after Luna 10 in 1966, and Luna 14 had mapped potential landing sites in 1968). To guard against the (increasingly likely-) possibility of further failures in the manned program, the government accepted Babakin's proposal from early 1967 to prepare an unmanned sample return probe (Hendrickx,1997). This would recover a few grams of lunar soil and return it to the USSR before the first American landing. This probe was called Ye-8-5 and used the same lunar descent propulsion module as the other Ye probes, but replaced the rover with an Earth return vehicle plus soil sample capsule (Hendrickx,1995). Design work on the "standard" Ye-8 was finished in late 1967.

The man-in-space program also got a new fallback option when Chelomei's Almaz military space station was confirmed. Chelomei had also developed a large cargo spacecraft called TKS using elements from the old LK-1 program, and we also know that he proposed a manned Mars flyby using an UR-700 heavy-lift rocket with a new nuclear upper stage (the LK-700 lunar landing project had been cancelled a year earlier). Mishin also was proposing a similar manned flight to Mars for the early 1990s (Clark,1992). The MK-900 Mars mission finally died in 1971 but the Almaz/TKS program was eventually merged with the Soyuz program in 1970, becoming the civilian `DOS-1' Salyut space station that dominated the Soviet space scene well into the mid-1980s.

The next two manned Soyuz flights would practise spacewalks and dockings, finally achieving the goals of the failed Soyuz 1/2 mission almost two years earlier. Soyuz 4 was the first to go, launched on 14 January 1969 with Vladimir Shalatov on board. On the 15th, Soyuz 5 carrying three more cosmonauts (Boris Volynov, Yevgeni Khrunov and Alexei Yeliseyev) joined Shalatov in Earth orbit. Following docking, Khrunov and Yeliseyev tested the new moonsuits by performing a spacewalk to Soyuz 4. The Soviets claimed the Soyuz 4/5 linkup represented 'the world's first space station' and denied they had plans to go to the Moon at the moment (Harvey,1996).

**EXPLOSION ON THE N1 PAD**

The Soviets were now ready to test their various lunar-landing spacecraft for the first time. The first to go was an unmanned Ye-8 lunar rover which would have landed on the Moon and relayed back TV pictures of the landing site. But its UR-500 rocket exploded 40 seconds after launch on 19 February 1969.

On 21 February the first N1 booster (number 3L) roared to life and the giant rocket began to rise skyward. However, at 12:19:12 Moscow time (66s after launch) a leaking oxidizer pipe started a fire at the rear of the first stage and the unmanned L1 payload's escape system activated, pulling it away from the booster. The N1 was destroyed by range safety while the L1 landed safely. Heat and vibrations from the first stage's 30 engines had damaged the rocket, it was later determined. The launch went virtually undetected in the West with only a British observation team reporting it, although CIA dismissed the report (Vick,1996).

The Soviets were now running out of time. The Apollo 9 astronauts successfully tested the Lunar Module in Earth orbit one month after the N1 launch failure, and in May the crew of Apollo 10 ventured to within 15 kilometers of the lunar surface in a dress rehearsal of the Apollo 11 mission. Only a miracle could save the Soviets, who nevertheless pressed ahead. The first two Ye-8-5 'Moonscopers' failed to reach Earth orbit in April and June, respectively.

After some changes, a second N1 launch attempt using rocket number 5L was made on July 3 at 23:18:32 Moscow time. Nine seconds after liftoff at an altitude of 200 meters, disaster struck. A piece of debris entered the oxidizer pump of one of the engines, causing it to explode. The explosion wiped out other engines and vital control systems, an the N1 engine control/thrust coordination system shut down the remaining engines. The launch escape tower then activated and pulled the payload (an unmanned L1 spacecraft) away from the booster, which fell back towards the pad. The resulting giant explosion completely destroyed pad 2 and also did significant damage to pad 1 and an N1 mockup 500 meters away (Lebedev,1992). CIA quickly discovered the damage when scrutinizing spy satellite photos of the Baikonur Cosmodrome a few weeks later.

The last Soviet hope was now the Ye-8-5 program and on 13 July 1969, an UR-500 booster finally hurtled Luna 15 towards the Moon. Three days later, Neil Armstrong, Edwin Aldrin and Michael Collins entered their Apollo 11 spacecraft as millions of people all over the world were watching the event on TV. But the Soviet probe's landing systems failed and it impacted on the Moon as the Western media was trying to figure out what its mission was. The same day, on 21 July 1969, Neil Armstrong became the first man to walk on the Moon. The Soviets had lost.

**PICKING UP THE PIECES**

The triumphant return of Apollo 11 on 24 July marked the ultimate humiliation for the Soviet space planners. Frustrated by one failure after another, the past two years had been marked by one misfortune after another. Beaten in the around-the-Moon race, beaten in the on-the-Moon race; even the Ye-8-5 Moonscooper had failed. Nothing seemed to go right. It was a dramatic contrast to the early 1960s when the Americans could do no right and the Soviets could not go wrong.

When it was found out that it would take two years to repair the N1 launch pads, rumors started to fly that the project might have to be cancelled altogether (Newkirk,1993). But Mishin still enjoyed enough support in the Politburo to keep the N1 alive. While the launch complex was being rebuilt, the N1 first stage engines were tested vigorously. Mishin was also ordered to begin work a more advanced manned lunar-landing project called L3M. If they could not be first, the Soviets reasoned, they could still be best. The program would eventually be reorganized around the concept of extended stays on the Moon that would be longer than the brief visits made by the American Apollo astronauts (Logsdon,1994). Meanwhile the triple flight of the Soyuz 6,7 & 8 spacecraft in November 1969 gave the Soviets something to cheer about, although that mission was part of the forthcoming Almaz space station program.

**UNMANNED TESTS AND LUNAR EXPLORATION**

The Ye Luna program finally began to yield results. After three more launch failures, Luna 16 finally became the first successful Ye-8-5 craft on 12 September 1970, returning a few grams of soil from the Sea of Fertility. It was a remarkable achievement by any standard. In October 1970, Luna 17 landed the first successful Ye-8 rover on the Moon. The vehicle, called `Lunokhod 1' by the Soviets, lasted nine months on the lunar surface and travelled almost 11 kilometers. The USSR now claimed the Lunas were ten times cheaper than Apollo and far less risky than a manned mission.

Meanwhile the L3 spacecraft were finally ready for launch. The LOK propulsion systems were to be tested in orbit using a prototype named T1K while the LK lander systems would be tested on another vehicle named T2K. Lack of funds (and available Proton boosters-?) meant the T1K was never launched. But the T2K flew three times in Earth orbit because Mikhail Yangel insisted that his propulsion module be tested thoroughly before a manned landing was attempted (Pirard,1993). The vehicles were tested secretly under the Cosmos label, but Western observers monitoring them still suspected a link to the manned space program (Harvey,1996).

The T2K tests took place in November 1970 (Cosmos 379), February 1971 (Cosmos 398) and August 1971 (Cosmos 434). Various contingency modes and the ascent from lunar orbit were simulated successfully and the LK lander was declared ready for manned flight following the Cosmos 434 tests (Pirard,1993). In December 1970, Cosmos 382 successfully tested the operation of the Block-D rocket stage in space, which would be used by the L3 complex during lunar orbit insertion and descent to the surface. Cosmos 382 consisted of a modified L1 spacecraft with instruments installed to monitor the behavior of the Block-D propellants under weightless conditions. A second launch in November failed to reach orbit.

At the same time, a manned test of the LOK/LK docking system in Earth orbit was planned. Two Soyuz craft would be outfitted with the `Kontakt' docking adaptor - a rather primitive system that permitted successful dockings with poor precision (van den Abeelen, 1994). The active crew, simulating the LOK, would be Anatoli Filipchenko and Georgi Grechko; the passive crew was Georgi Dobrovolski and Vitaly Sevastianov. However, it was eventually decided to replace the `Kontakt' system with a new one called `Igla' and the mission was cancelled in January 1971 (Harvey,1996).

## PLANNING THE ADVANCED L-3M PROGRAM

The Soviets were now ready to fly the N1 again two years later. Perhaps in order to conceal the true purpose of the launch, the new N1 (number 6L) was not aimed at the Moon. The goal was simply to launch a dummy LOK into Earth orbit. This launch took place from pad number two on 27 June 1971 at 02:15:07 Moscow time as three cosmonauts flew overhead in the new Salyut 1 space station. Soon after liftoff at an altitude of about 250 meters an unplanned rotation caused breakup of the support structure between the second and third stages. Moments later the third stage and lunar complex toppled over, falling near the launch pad and causing damage. The rest of the N1 impacted 20km downrange.

Despite the failure the Soviets continued the N1 program, but it appears as if plans for (L3-) lunar expeditions were abandoned for some time due to the success of Apollo. (Lebedev,1992). Instead, Mishin presented his now complete plan for the L-3M project to the Council of Chief Designers, which formally approved it in the spring of 1972. The L-3M envisioned a manned lunar mission of two N1 rockets with new high-energy cryogenic upper stages to boost performance. The first N1 would place a large 25t lunar lander descent stage (GB-1) in lunar orbit. The second N1 would deliver a three-man GB-2 lunar lander/Earth return vehicle weighing 24t. Both payloads would dock in lunar orbit and then descent together to the lunar surface. The GB-2 would permit 2-3 cosmonauts to spend up to a month on the lunar surface, using a Soyuz capsule for the return to Earth (Vick 1996). Mishin envisaged the dual N1 mission taking place in the late 1970s (Harvey,1996). But it appears as if the Soviet government never funded the construction of actual L-3M hardware and the remaining unmanned test flights had to use existing L3 spacecraft in the end.

## MORE N1 FAILURES

The fourth and, as it turned out, final N1 rocket blasted off from pad number two early in the morning on 23 November 1972 at 09:11:52 Moscow time. The rocket had been extensively designed since the last failure. The 1st stage engine bay had been redesigned and its diameter (originally 16.8 meters) was reduced to 15.8 meters. Another visible change was that the kerosene pipeline covers on the first three stages were sharpened at the top. The fourth N1 booster (number 7L) was heavier than its predecessors but also designed to be more reliable (Yasinsky,1993).

This time all went well until the 90s mark, when there was a failure of a 250mm line from the liquid oxygen tank. A fire broke out, engines started to explode and the entire 1st stage was shut down 107 seconds into the flight a mere six seconds before second stage separation . . . The escape rocket pulled the payload (an unmanned real LOK

orbiter) away from the rocket, which was then destroyed by range safety. Close, but still no cigar.

**END OF THE ROAD**

The lunar programs of both superpowers tapered off in 1973. Apollo 17 had successfully concluded the American man-on-the-Moon program in December 1972; future missions would be restricted to Earth orbit. The Soviet Luna program was scaled back as well. In January 1973 Luna 21 landed another Ye-8 rover (Lunokhod 2). In May the following year the last Ye-8LS lunar orbiter, Luna 22, was launched (Luna 19 had carried out a similar observation program from lunar orbit in 1971). Luna 19 managed to return soil samples to Earth in February 1971 but two more Ye-8-5 probes had failed by the end of 1974.

Mishin still pressed on. Two new N1s were constructed (vehicle no. 8L and 9L), the first set for launch in August 1974 and the second later that year. The purpose was now to fly the entire L3 mission in an unmanned mode, including a lunar landing. Engineers said that by 1976 the N1 may have become operational (Lebedev,1992). If the missions had gone well, there were plans to use the 10L vehicle to land the first Soviet cosmonaut on the Moon. An alternative plan was to fly an Apollo 10 type dress rehearsal mission, practising spacewalks between the LK and LOK in lunar orbit before the LK made an automatic landing and return to the manned LOK. The first manned landing would have been performed by the 11L vehicle in that case. At least four to five follow-up lunar expeditions (up to N1-15L or 16L) were originally planned (Hendrickx,1995). It would seem that the manned LK/backup LK launch scenario proposed in 1965 was considered for the first manned landing only.

That day never arrived, however. Mishin had came increasingly under fire not only for the failures of the L1/L3 programs but also for the problems of the Salyut space station program. In May 1974, Mishin was dismissed and replaced by Valentin Glushko - Korolev's old enemy. Within days, Glushko suspended the lunar program, instead presenting his own plans for a lunar colony. During 1974-76 he worked on an entirely new heavy-lift rocket called Vulkan that would have used oxygen and hydrogen fuel just like Korolev had wanted in 1962! Drawings were made of a large manned lunar rover that would have carried cosmonauts across the lunar surface. His plans were opposed by Mstislav Keldysh and the Academy of Sciences, who regarded them as both expensive and premature. Neither the government nor the military were interested. Both regarded the new American Space Shuttle as a bigger (military-) threat so Glushko was ordered to plan a similar Soviet system. The N1 was finally terminated in March 1976 when Glushko began work the Soviet shuttle project. His Vulkan booster became the Energia booster and would instead be used to launch the Shuttle. The remaining six N1s were destroyed (Mishin, 1990; Harvey,1996). The last Soviet lunar probe (Luna 24) departed from the Moon in October 1976.

**EPILOGUE**

Had the N1 succeeded, it would have been called the `Lenin' or `Kommunism' booster. Instead it disappeared almost without a trace. Scavenged pieces of the superbooster were used as makeshift hangars and storage sheds at the Baikonur Cosmodrome (Landis,1992). The launch pads and vehicle integration buildings were converted to support Glushko's Energia program instead, and the first of the new superboosters took off from the old N1's second pad in 1987. Only the N1's NK-33 engines survived, being perfected by Kuznetsov at his own expense after the N1 program ended. In 1996 they were sold to two American companies to be used on the first stage of new reusable spacecraft! Four surviving LK landers and one LOK ended up in museums or space engineering institutes, where they are used for study today. Mishin was also sent to lecture at the Moscow Aviation Institute and, following Glushko's death in 1989 and *glasnost*, emerged to tell the story of the Soviet lunar program.

Writing about the N1 and L3/L1 projects years later, Mishin blamed underinvestment (only $4.5 billion compared to Apollo's $24 billion), lack of cooperation between design bureaus, failure to grasp the significance of President Kennedy's challenge as well as the technical difficulties of sending humans to the Moon. They should also have done ground testing. Poor management of the 500 enterprises and 26 government bureaus involved was also a major problem (Harvey,1996).

The direct technical reason for the N1's failure was its inability to achieve reliability and thrust stability across the 30 NK-33 first stage engines (Landis,1992). But the real, principal reasons were that (1) the Soviets entered the Moon race far too late; (2) the lack of cooperation between the leading personalities such as Korolev/Mishin vs.

Glushko/Chelomei. The resulting duplication of effort was something the Soviets could afford even less than the Americans. In the end, the USSR lost the race to the Moon because it misjudged American intentions and resources, mobilized its own resources far too late, and failed to control its competing schools of rocket/spacecraft designers (Harvey,1996).

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