

Heavy Launch Vehicles of the Yangel Design Bureau - Part 2

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This paper explores efforts by the OKB-586 design bureau of Mikhail Yangel to develop heavy launch vehicles in the first half of the 1960s. None of these projects ever came to fruition, mainly because they could not stand up to the competition from similar rockets developed by the OKB-1 of Sergei Korolyov and OKB-52 of Vladimir Chelomei. Several Russian publications have shed new light on the history of these hitherto little-known booster proposals.

Keywords: Mikhail Yangel, OKB-586, RK-100, R-46, R-56, N-1, Soviet lunar programme

6. The R-56

6.1 The Birth of the R-56

By the end of 1961 no final decision had yet been made on the propellants to be used on the N-1. Korolyov and Glushko discussed the issue on 10 November, but reached no consensus [38]. However, if the choice eventually fell on Kuznetsov's LOX/kerosene engines, the effort invested into the RD-253 would not be in vain. The engine had good prospects of flying on Chelomei's UR-500 and Glushko was now also contemplating using it for a bigger Yangel rocket that would have more than double the payload capacity of the UR-500. He outlined his newest ideas on 29 November 1961 in a letter to Ivan D. Serbin, the chief of the Defence Industries Department of the Central Committee of the Communist Party, who reported directly to the Secretary of the Central Committee for Defence Matters, essentially the head of the space programme in the Soviet days. Repeating his conviction that the RD-253 and RD-254 were the engines best suited for the N-1, Glushko also promoted their use on a rocket that could be developed within a shorter period of time. Although he also called it the R-46, it was a much bigger vehicle than the one he had put forward to Yangel earlier in the year. With a lift-off mass of between 1000 and 1200 tons, it would use clustered first and second stages and an additional third stage to orbit payloads of 30 to 35 tons. He also underlined that the R-36 could be equipped with a third stage to launch 4.5 ton payloads, but stressed that "the R-36 and R-46 are, of course, intended in the first place as ballistic surface-to-surface missiles" [39].

The letter was written only one month after the detona-

tion of a massive Soviet hydrogen bomb officially called AN-602 (Fig. 9). Nicknamed "Ivan" by the Russians and the "Tsar bomb" in the West, the device was dropped from a specially modified Tu-95N bomber over Novaya Zemlya island in the Arctic Sea on 30 October 1961. The test was timed to coincide with the 22nd Communist Party Congress in Moscow and had been announced in advance by Khrushchov at the beginning of the Congress. The AN-602 was originally designed to have a yield of about 100 megatons of TNT, but that was reduced in half to limit the amount of nuclear fall-out. Nevertheless, it remains the most powerful nuclear device ever tested by any nation and was four times more powerful than any Soviet nuclear weapon exploded before. The detonation of the "Tsar bomb" marked the culmination of a new series of nuclear tests begun by the USSR in September 1961 in the wake of increasing Cold War tensions following a nearly three-year de facto moratorium on nuclear tests between the Soviet Union, the United States and the United Kingdom. Initial development of a 100-megaton nuclear device (RN-202) had begun at the NII-1011 institute in Chelyabinsk-70 in 1955, but was suspended by the end of the decade. Construction of the derived AN-602 was ordered by Khrushchov in July 1961 and assigned to the KB-11 bureau in Arzamas-16, which finished the job in just over three months [40].

With a reported mass of 26.5 tons, a weapon like the AN-602 would have been too heavy to be delivered to the United States by the Tu-95 and, at any rate, any such bomber would have been detected crossing the North American early warning line well before actually reaching

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Fig. 9 The AN-602 hydrogen bomb.

US territory, giving jet fighters ample time to intercept and shoot it down. Shortly after the AN-602 test, Nikita Khrushchov reportedly ordered his rocket designers to devise a missile that could handle the job [41]. Whether Glushko's latest proposal was a direct response to that request is not clear, but the new missile was exactly the kind of machine needed to transport such deadly weapons over intercontinental distances. Again, the available evidence points to Glushko taking the initiative and it is unclear what Yangel's role in the initial decision-making process was. In December 1961 Glushko and Yangel are said to have formulated a joint proposal for the new rocket, which was now called the R-56 (also 8K68). With a launch mass of 1200 tons, it was capable of carrying a 35-ton nuclear warhead over a 16000 km distance or putting a 30-ton payload into low Earth orbit [42].

On 15 January 1962 several leading Soviet defence officials, including Defence Minister Rodion Malinovskiy, sent draft decrees to the Central Committee of the Communist Party for the development of two new nuclear weapon delivery systems. One was OKB-1's GR-1, a global missile, and the other Yangel's R-56. Apparently, by this time the Ministry of Defence was becoming alarmed that some of the timelines for missile development set by earlier government decrees were not being met. These concerns were expressed by Malinovskiy and General Staff chief Matvei Zakharov in a letter to the Central Committee on 2 February 1961, in which they called for better coordinating the nation's missile programmes and "clarifying sources of financing" for missile projects [43]. The letter may have set the stage for a meeting later that month of the Soviet Defence Council, established on 7 February 1955 to make recommendations on key national security issues. Chaired by Khrushchov, this was a civilian/military body that consisted of the leaders of the Council of Ministers (the Soviet government), the Supreme Soviet (the Soviet parliament), the Ministry of Foreign Affairs and the Ministry of Defence. Actually, Khrushchov himself seems to have been dissatisfied with the coordination of missile programmes, which was the responsibility of the Central Committee of the Communist

Party. Most of the decrees on missile affairs had been drawn up without much discussion by the Central Committee on the initiative of the chief designers. As a result, many of them overlapped one another, leading to a wasteful duplication of effort. Now Khrushchov decided that the Defence Council should take over that initiative, with the Central Committee and the Council of Ministers turning its decisions into decrees. In this way, the military could always be called to responsibility if things went wrong because the Defence Council included both the Minister of Defence and his first deputy [44].

Until then Defence Council meetings had taken place behind closed doors in the Kremlin and had been attended by its select few members, but this time Khrushchov decided to organize a big meeting with "outsiders" at his *dacha* in Pitsunda near the Black Sea on 12-13 February 1962 [45]. Among the invitees were Korolyov, Chelomei and Yangel, who were all given the chance to present their latest missile and space plans to the nation's top brass. Chelomei talked about his new UR-500 booster, capable of launching 30-megaton warheads or 12-ton satellites, and Korolyov gave an update on the N-1, not forgetting to mention that besides its space-related tasks it could carry 100-megaton nuclear weapons. When Yangel's turn came, he first elaborated on the newly conceived R-36 missile and then moved on to the 1200 ton R-56, advertising it as a launch vehicle of space stations and 50-megaton warheads. However, Khrushchov, having been bombarded with ideas for two days on end, was not impressed and turned down Yangel's idea, mainly because the rocket had no clear-cut goal. As Khrushchov's son Sergei writes in his memoirs: *Had [Yangel] had the luck of being the first to make his presentation, I think his [R-56] proposal would have been accepted, but now...*. Khrushchov tried to soften the blow for Yangel, saying OKB-586 was the leading design bureau of the nation's strategic missiles and that it should not be distracted from its main task [46]. The Defence Council gave a special commission one month to formulate recommendations for the further use of ICBMs, global missiles and space rockets. These would have to result in a major new party/government decree on the future course of Soviet missile and rocket development. The commission consisted not only of leading government and party officials, but also the chief of the General Staff and the Commander-in-Chief of the Strategic Rocket Forces [47].

6.2 The "Small" and "Big" R-56

In the ensuing weeks some major lobbying appears to have taken place behind the scenes. On 12 March 1962 Glushko sent a long letter to two leading members of the commission [48]. One was Leonid Smirnov, who had taken over from Konstantin Rudnev as chairman of the GKOT in June 1961, and the other Dmitriy Ustinov, the chairman of the Military Industrial Commission (VPK), a

powerful government body that oversaw the entire defence industry. Two days later he sent a virtually identical letter to the Commander-in-Chief of the Strategic Rocket Forces Kirill Moskalenko, another commission member. Glushko provided an overview of the heavy-lift booster proposals he had made in the preceding years (R-8, R-10, R-20, R-46) and formulated the latest plans for the R-56. Surprisingly, he mentioned not only the “30-ton” R-56, but also a version with a payload capacity of 70 tons to a 300 km orbit, rivalling that of the N-1 (which he gave as 73 tons). He did not use a separate designator for the 70-ton version, which is why the two will be further referred to here as the “small” and the “big” R-56.

By using standardized, clustered rocket modules, the big R-56 would be a logical outgrowth of the smaller one with no major leap in technology required to more than double the payload capacity. Quite possibly, the 70-ton version of the R-56 had been under study for some time, although there is no evidence it was presented to Khrushchov during the Pitsunda meeting [49]. Rather than offer the R-56 as a stand-alone proposal, the new “package deal” offered significant cost savings by eliminating the need to build two basically different rockets to serve two different payload niches.

Although Glushko gave few details of the exact configuration, he described the “small” R-56 as a “four-block” booster with a total of 17 engines and the “big” R-56 as a “seven-block” rocket with a total of 28 engines. Both rockets would have three stages and use “unified” engines burning N2O4/UDMH. Based on this information, an attempt to reconstruct the configuration of both rockets is made in Table 3.

The small R-56 would have used first and second stages both consisting of four modules with a single third-stage module mounted on top of the second stage. The big R-56 would have had a first stage made up of seven modules (one in the centre, six strapped around it). The third stage would have been on top of the central module of the first stage, with the six second-stage modules clustered around the third stage and peeling away from it after burnout of the engines. The first-stage modules would each have been equipped with three RD-253 engines and the second and third-stage modules with a single RD-254 engine. The diameter of the modules was presumably around 3.4 m.

In his letter Glushko summed up several advantages that the big R-56 offered over the N-1:

- 1) the modular concept made it possible to use the small R-56 as a test bed for its bigger cousin and also to transport ready-made rocket modules to the launch site by rail. The preferred design for the N-1 by now was a so-called “monoblock” rocket with three

TABLE 3: Probable Configuration of the Small and Big Versions of the R-56 Proposed in March 1962.

	Small R-56	Big R-56
Lift-off mass	1200 t	2100 t
Stage 1		
Modules	4	7
Engines	12 x RD-253	21 x RD-253
Propellants	N2O4/UDMH	N2O4/UDMH
Thrust (sea-level)	151 t	151 t
Specific impulse (sea-level)	285 s	285 s
Total amount of combustion chambers	12	21
Combined thrust	1812 t	3171 t
Stage 2		
Modules	4	6
Engine	4 x RD-254	6 x RD-254
Propellants	N2O4/UDMH	N2O4/UDMH
Thrust (vacuum)	175 t	175 t
Specific impulse (vacuum)	330 s	330 s
Total amount of combustion chambers	4	6
Combined thrust	700 t	1050 t
Stage 3		
Modules	1	1
Engines	1 x RD-254	1 x RD-254
Propellants	N2O4/UDMH	N2O4/UDMH
Thrust (vacuum)	175 t	175 t
Specific impulse (vacuum)	330 s	330 s
Total amount of combustion chambers	1	1
Combined thrust	175 t	175 t

massive, single-piece stages, many elements of which would have to be welded together at the launch site.

- 2) the rocket had a total of 28 engines compared to “from 34 to 52” on the N-1 [50]. Furthermore, they were all of the same type. Obviously, the smaller amount of engines reduced the risk of random failures, but Glushko considered even 28 engines close to the acceptable limit, noting that even this amount compared unfavourably to the number installed on America’s Saturn-1, Saturn-5 and Nova rockets (14, 11 and 13 respectively).
- 3) the use of hypergolic, storable propellants simplified the ignition sequence (both on the ground and in vacuum) and also the simultaneous ignition of multiple engines on a single stage. Moreover, engines burning these propellants were less prone to high-frequency pressure oscillations in the combustion chamber than LOX-based engines. The only drawbacks of these propellants were their high toxicity and their relatively high cost.
- 4) unlike the LOX/kerosene engines proposed for the N-1, the RD-253 had been under development at OKB-456 for about a year and components were already undergoing extensive testing. Therefore, the big R-56 would be ready to fly sooner than the N-1.
- 5) the big R-56 would have a smaller diameter and length than the N-1, even though its lift-off mass (about 2100 tons) and payload capacity (about 70 tons) were virtually identical.

All these factors left no doubt in Glushko's mind that the R-56 would be a better choice than the N-1. He rejected ideas for OKB-1 and OKB-586 to join forces in building the first three stages, giving no indication who had actually come up with them. One such idea was to combine the R-56 first stage with the second and third stages of the N-1, but according to Glushko this would result in a hybrid rocket with four different types of propellant and (for reasons that are not entirely clear) a total of 52 engines, leading him to conclude this was not a rocket, but "an engine depot". He also cited OKB-1 studies showing that if the N-1 were to switch to N2O4/UDMH in its current configuration, the payload capacity would decrease from 73 tons to about 60 tons. Interestingly, only months earlier he had claimed that an N-1 with N2O4/UDMH rather than LOX/kerosene in the first two stages would *increase* the payload mass [51], but with an alternative heavy-lift rocket now on the table that was tailored to use his engines, Glushko apparently found it convenient to refer to the OKB-1 research. After all, OKB-586 calculations showed that despite the use of storable propellants, the big R-56 would have about the same lift-off mass and payload capacity as the N-1.

Since the big R-56 used the same type of engine in all three stages, Glushko saw no need to involve OKB-1 in the rocket's design. He did, however, favour co-operation between the two design bureaus on a different level. While OKB-586 would bear sole responsibility for the first three stages, OKB-1 could concentrate on the upper stages and payloads, an area where it had much more experience than OKB-586. Still, OKB-1 was not willing to share a piece of the pie. As Glushko wrote: *"OKB-586 understands the expediency of such a division of labour and has supported it from the beginning of the R-56's development. OKB-1 interpreted this as an infringement of its interests. However, this issue has exceeded the jurisdiction of individual chief designers and must be ... decided on the highest level"*. Concluding the letter, Glushko stressed that any further delays in the development of a launch vehicle more capable than the Saturn-1 or UR-500 would cause the Soviet Union to lag further behind the United States in rocket technology "with all the resulting serious political, military and scientific consequences".

Meanwhile, Korolyov had not been sitting idle either and had conceived a smaller version of the N-1 that was comparable in performance to the small R-56. On 5 March 1962 he sent a letter to several of the commission members, outlining OKB-1's latest plans for the R-9 and GR-1 missiles, the Soyuz project and the N-1. One key new element was a suggestion to build a rocket made up of the second and third stages of the N-1 that would not only be a "pathfinder" for its bigger cousin, but also serve as a launch vehicle in its own right. Called the N-2 (not to

be confused with the identically labelled "nuclear" rocket mentioned in the June 1960 decree), it could be used as an ICBM (to deliver a single 25 megaton warhead), a global missile (to deliver six to seven 2.2 megaton warheads) or a space launch vehicle (with a payload capacity of about 25 tons to low Earth orbit). An early version of the N-2 would use only the NK-9 engines (then already being tested for the first stage of the R-9M and GR-1 missiles as well as the third stage of the N-1) and be ready to fly as early as late 1963, but eventually the first stage would be equipped with the same engines planned for the N-1 first stage (NK-15) [52].

As a result, the commission set up after the February 1962 Pitsunda meeting was faced with a choice between Korolyov's N-1 and N-2 on the one hand, and Yangel's small and big R-56 on the other hand. Both offered a vehicle in the 25 to 30-ton payload range that could also act as a super ICBM or FOBS system and an outgrowth with a 70-ton launch capacity.

6.3 Cautious Go-Ahead for the R-56

The final decision came on 16 April 1962 in a government and party decree (No. 346-160) called "On the most important projects of intercontinental ballistic and global missiles and carriers of space objects". It called for concentrating efforts on the development of Chelomei's UR-500 (as an ICBM, global missile and space launch vehicle), UR-200 (as an ICBM and a global missile) and Yangel's R-36 (as an ICBM and a global missile). Korolyov's GR-1 global missile was to be further evaluated before final approval was given.

In a clear sign that the development of heavy-lift space rockets was not considered a priority, the decree ordered to limit the work on such boosters in 1962 to "draft designs" and also called for "economically justifying the cost of these carriers". The two rockets approved for further study were the N-1 with a payload capacity of up to 50-60 tons (although OKB-1 was already assuming a 70-ton capacity) and the R-56 with a payload capacity of up to 30 tons. Despite the rejection of the big R-56, the inclusion of the smaller version in the decree must still have come as a pleasant surprise to Yangel's team, especially after Khrushchov's negative reaction at the Pitsunda meeting in February. One can only speculate why it was decided to opt for two radically different boosters rather than pick one of the two package proposals, which—at first sight at least—offered significant cost savings.

The choice of the N-1 to represent the heavier payload class was perhaps logical because by this time design work on the rocket had been underway for almost two years, whereas the R-56 had been conceived only months

earlier. However, the commission members may have been reluctant to put all eggs in one basket by recommending the N-2 as well. If the test flights of the N-2 uncovered some basic design flaws, this would significantly delay or even put in jeopardy the development of the N-1. The selection of the R-56 in the lighter payload class would leave open the option of building the big R-56 as an alternative to the N-1 in a reasonable amount of time if that turned out to be necessary.

There must also have been very practical reasons for taking up the R-56 in the decree. The R-56 nicely filled the significant gap in payload capacity between the UR-500 (12-13 tons) and the N-1 (50-60 tons). Even though few, if any, concrete payloads in the 30-ton mass range had been clearly defined at the time, evidently there must have been confidence that such payloads would materialize in the not too distant future. Korolyov's N-2 with its 24/25-ton capacity was inferior to the R-56 and, more significantly, was only slightly more powerful than a three-stage version of Chelomei's UR-500 (UR-500K) with a 20-ton payload capacity, which was approved in a party and government decree on 24 April 1962 (No.409-183) [53].

Apparently, the possibility to use the R-56 as a super ICBM or FOBS launch vehicle had not been a major factor in the decision. This potential application of the rocket was not mentioned in the decree and had clearly taken a backseat to its role as a space launch vehicle, if it was still seriously considered at all. Theoretically, the R-56 was capable of launching 100 megaton nuclear warheads as a ballistic missile and 50 megaton nuclear devices as a global missile [54]. However, the detonation of the "Tsar bomb" in October 1961 is believed to have been a one-and-off test aimed at demonstrating the Soviet Union's nuclear might to the world. Khrushchov, well known for his whimsical behaviour, may well have ordered the development of a missile to carry such bombs in a flush of enthusiasm after the successful test, but had apparently already cooled to the idea by the time of the Pitsunda meeting. There is no convincing evidence that 50 to 100 megaton thermonuclear bombs were ever produced as operational weapons or that there was any elaborate plan to do so. The destructive force of a 100-megaton weapon was so enormous that if detonated over Western Europe, the nuclear fallout could produce lethal exposures extending all the way into the Warsaw Pact countries. In fact, the test is said to have had a "sobering effect" on the Soviet missile designers [55]. Moreover, gradual improvements in guidance systems made it possible to more accurately deliver warheads to their targets, as a result of which their yield and mass could be reduced. When Khrushchov convened another meeting of the Defence Council on missile affairs in February 1963, delivery systems for such massive nuclear bombs were

no longer on the agenda [56]. In the end, the only ICBM role studied in earnest for the R-56 was to carry a cluster of smaller warheads (so-called Multiple Re-entry Vehicles or MRVs) that are less vulnerable to interception by anti-ballistic missiles. This work is said to have reached the stage of the "pre-draft design" [57].

Finally, there may have been political pressure behind the scenes to introduce Yangel's bureau as a third player in the heavy-lift launch vehicle business alongside OKB-1 and OKB-52. One man who may very well have been instrumental in getting the R-56 proposal passed was Leonid Smirnov, one of the members of the commission that prepared the 16 April 1962 decree (Fig. 10). Smirnov had long been a close associate of Yangel, having headed the production facility aligned with Yangel's OKB-586 bureau from 1952 until 1961. In 1961 he was transferred from Dnepropetrovsk to Moscow to become a Deputy Chairman and later that same year Chairman of the State Committee of Defence Technology (GKOT), whose 7th Chief Directorate would be reorganized in 1965 as the Ministry of General Machine Building (MOM). In March 1963 Smirnov would be promoted to the even more influential post of Chairman of the Military Industrial Commission (VPK) [58].

The 16 April 1962 decree necessitated a shift of focus in OKB-586's space-related activities. Not long after the decree was passed, Yangel organized a major meeting at the design bureau, where a decision was made to transfer four space projects to two other design bureaus. A lightweight booster based on the R-14 missile as well as two small military communications satellite systems (Pchela and Strela) would now be developed by the newly founded OKB-10 (later NPO PM) near the Siberian city of Krasnoyarsk, while the development of the Soviet Union's first meteorological satellites would be handed over to a Moscow-based organization called VNIIEM (All-Union Scientific Research Institute of Electromechanics). All these projects had originally been assigned to Yangel's bureau by a government decree released on 30 October 1961 [59]. Assigned to the post of lead designer of the R-56 was 25-year old Stanislav N. Konyukhov, after he had recovered from injuries sustained in the explosion of an R-14 missile in a silo at the Kapustin Yar launch site on 11 April 1962 [60]. Later, in 1990, Konyukhov went on to head the Yangel design bureau (renamed KB Yuzhnoye in 1966), a post he held until September 2010.

6.4 The Design of the R-56

Not very much progress seems to have been made on the R-56 design in the first year after the April 1962 decree. Presumably, the design with the four first-stage modules remained unchanged during this period. Glushko's OKB-456 began extensive work on the RD-



Fig. 10 Leonid Smirnov.

253 first-stage engine, not only for the R-56, but also for Chelomei's UR-500. However, as the months progressed, it was becoming ever clearer that the engine would not be selected for the N-1. The choice of rocket engines for the lower stages of the N-1 was definitively settled in favour of Nikolai Kuznetsov's NK LOX/kerosene engines by a party/government decree in September 1962, effectively ending the cooperation between Glushko and Korolyov.

An alternative idea for the R-56 first stage was to replace the RD-253 engines with a much smaller cluster of powerful RD-270 (8D420) engines. The RD-270 was developed on the basis of a party/government decree (No. 631-257) of 26 June 1962 and a GKOT order (No. 434) of 18 July 1962 [61] (Fig. 11). It was essentially the Soviet answer to the American F-1 engine, although it used UDMH/N₂O₄ rather than LOX/kerosene. The decree had called for studying possible configurations of single-chamber engines with a thrust of "up to 1000 tons", but preliminary research conducted even before the decree showed that for the time being the highest attainable sea-level thrust would be 500 tons. Glushko reported these conclusions in letters to Yangel on 31 May and Chelomei on 3 July 1962. At that point, the RD-270 was not yet assigned to a particular rocket, with Glushko advising Yangel to start working on such a launch vehicle "right after the development of the R-56" [62]. The idea to mount the engines on the R-56 *itself* did not come until the second half of 1962 [63]. By January 1963 OKB-456 had come to the conclusion that the thrust could be

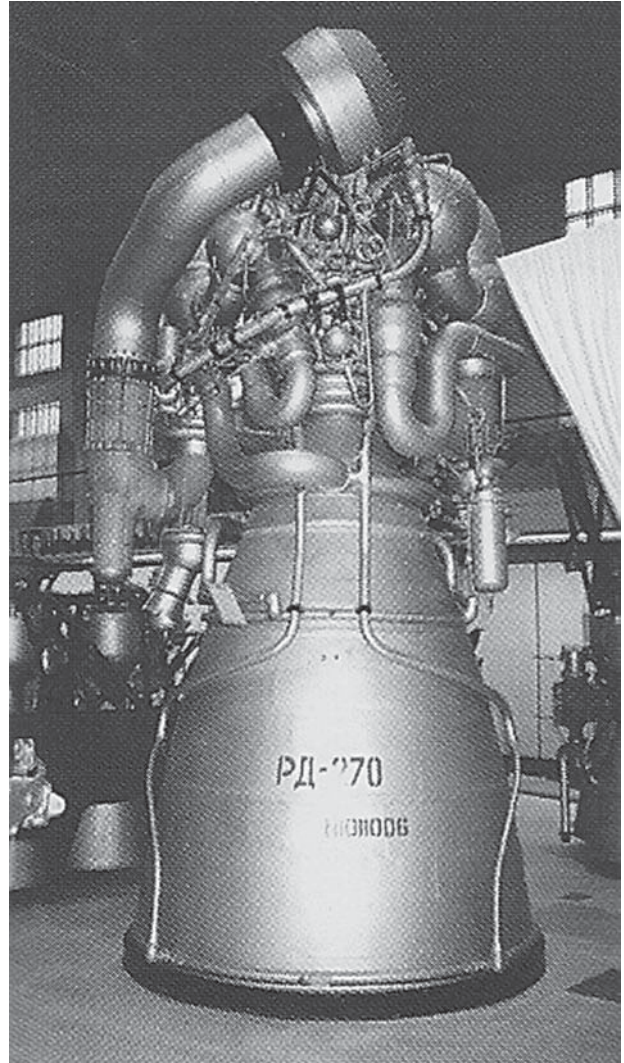


Fig. 11 The RD-270 engine.

increased to 600 tons, meaning that just a handful would be sufficient to replace the big cluster of RD-253 engines. As configured for the R-56, the engine would have a 12° gimbal capability in one axis [64].

On 22 May 1963 the Soviet government issued another decree which determined that the "draft design" for the R-56 should be finished in the third quarter of the year, assuming that test flights would begin in 1965 [65]. In August Leonid Smirnov, now the head of the VPK, chaired a meeting to discuss the draft design. It was attended among others by Sergei A. Zverev, who had succeeded Smirnov as Chairman of the GKOT in March 1963. A decision was made to turn the R-56 into an even more powerful rocket with a launch mass of about 1400 tons and a payload capacity of 40 tons to a low polar orbit and 46 tons to a low 49° inclination orbit, roughly the payload capacity of the original version of Korolyov's N-1. This requirement resulted from several studies made over the previous months by both military research institutes and OKB-586 itself, which indicated that this would be the payload mass required to orbit a wide variety of military, lunar and planetary missions. In order to meet

this new objective, OKB-586 reportedly had to make considerable changes to the existing draft design and “essentially created a new rocket” [66]. In fact, three different configurations were now contemplated for the rocket, two “polyblock” versions with seven and four modules on the first stage respectively, and a “monoblock” version (Fig. 12).

The three configurations nicely reflected some of the constraints imposed on Soviet designers in their attempts to construct heavy-lift launch vehicles in the 1960s. The Russians had maintained a rather conservative approach to increasing the thrust of their rocket engines, electing to do this step by step rather than in big leaps. By the early 1960s, the most powerful Soviet rocket engines had a thrust of no more than 150 tons, a far cry from the 680 ton thrust F-1 engine then under development for NASA’s Saturn boosters. This meant that a large amount of engines had to be installed in the first stage in order to generate the thrust required to lift massive rockets off the ground. Obviously, the larger the number of engines, the more complex the design and the more prone it was to failure. A large number of first-stage engines also translated into a large base diameter, but rail transport, the only efficient way of delivering rockets to the Baikonur cosmodrome, limited the maximum diameter to about 3.8 m. This in turn left designers with three options: a) build “polyblock” stages consisting of individual ready-made modules that would be shipped to the cosmodrome by rail and assembled at the launch site; b) build “monoblock” stages at the launch site from individual components delivered by rail (the option chosen for the N-1) c) build monoblock stages at the production facility and transport them to the launch site in one piece by unconventional means (air, water, road).

The first “polyblock” version had the same configuration as the originally proposed “big R-56”, with seven modules on the first stage and six second-stage modules clustered around a single third-stage module. However, the diameter of the modules was now just 3.0 m, which limited the amount of RD-253 engines on the first stage to two per module (compared to three on the “big R-56”) [67]. The advantage of this was that the production facility aligned with OKB-586 already had experience with the manufacture of 3.0 m modules for the R-16 and R-36 missiles.

The second polyblock version had the same lay-out as the originally proposed “small R-56”: four modules on the first and second stage and a single third-stage module on top of the second stage. The modules had a diameter of 3.800 m, the maximum that could be transported by rail, and therefore the first stage could house four RD-253 engines in each module rather than three on the original version. This design of the modules had already been

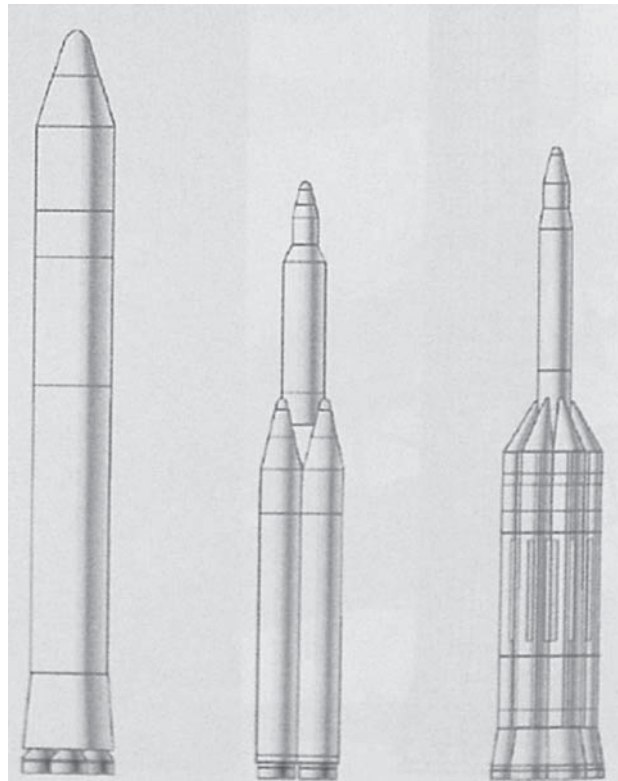


Fig. 12 “Monoblock” and two “polyblock” versions of the R-56.
(source: Art-Press)

studied for the R-46 rocket in 1961. A test model of this version of the R-56 is on display at the TsNIIMash museum in Korolyov outside Moscow [68] (Figs. 13 & 14). The available sources say that both polyblock versions would have had RD-254 engines in the second and third stages, but it should be noted that in that case the total thrust of the second stage (about 700 tons for the “four-block” version and 1050 tons for the “seven-block” version) would have been far more than what was actually needed.

In the end, the choice fell on the monoblock rocket, which would be assembled at the factory in Dnepropetrovsk. Clearly, the disadvantage was that the production facilities essentially would have to be rebuilt and, more importantly, that the rocket could not be transported to the launch site by rail. However, studies performed in cooperation with other organizations (including NII-88 and the Ministry of Defence) showed that these disadvantages were outweighed by a number of other factors. The monoblock version would be the cheapest to build and require the least R&D time since it used the same basic tandem arrangement as the R-16 and R-36. It would also require less preparation time at the cosmodrome and would have the simplest launch facility. It was also felt that the new production facilities needed for such a rocket would come in handy later on to build even more powerful launch vehicles with other, more energetic types of propellants, such as the ones that would be required to send manned missions to other planets.

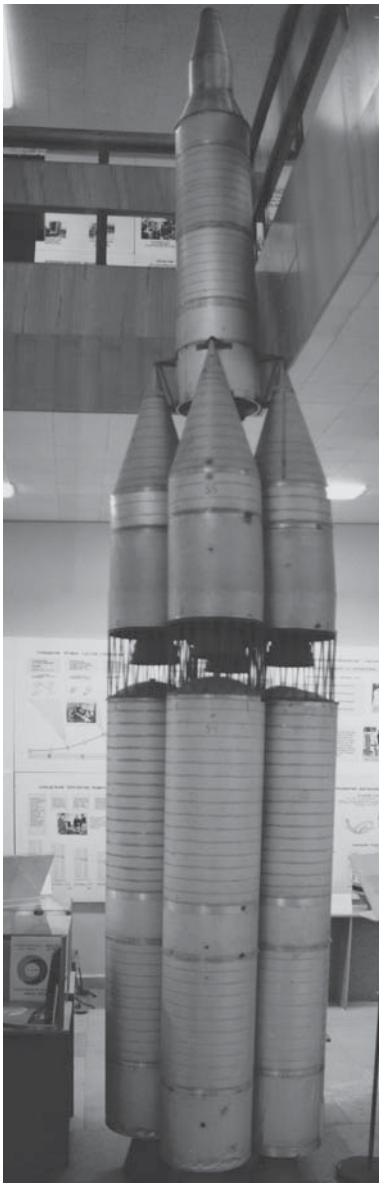


Fig. 13 Model of a "polyblock" R-56 at the TsNIIMash museum.
(source: Mark Wade)

The monoblock R-56 could be flown in four configurations depending on the payload it was carrying. A two-stage version would be used to place heavy objects into low Earth orbit and three-stage and four-stage versions were available for orbiting geostationary payloads and sending spacecraft to the Moon and the planets. The first and second stages had a basic diameter of 6.5 m, but the first stage had a flared 8.2 m diameter base to accommodate the engine assembly. The third stage tapered down to a diameter of 4.0 m. In its four-stage version, the rocket would stand 67.80 m tall on the launch pad (Fig. 15) (Table 4). The third and fourth stages had special thermal shielding to remain functional in orbit.

The first stage carried sixteen RD-253 engines. Twelve of the main engines were fixed, while four were gimbaled in pitch to provide steering for the launch vehicle. Such a steerable version of the RD-253 was already under de-

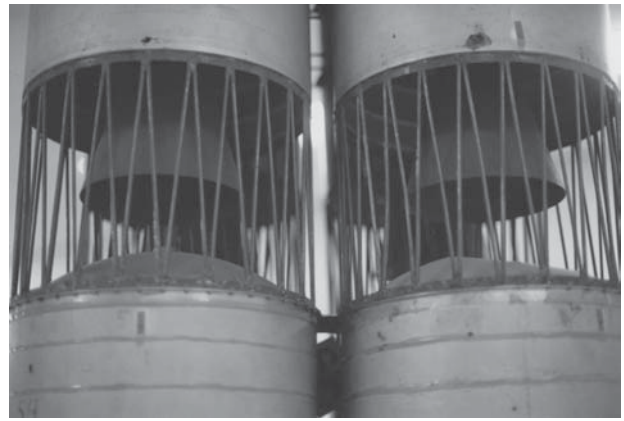


Fig. 14 Close-up of the second-stage engines.
(source: Mark Wade)

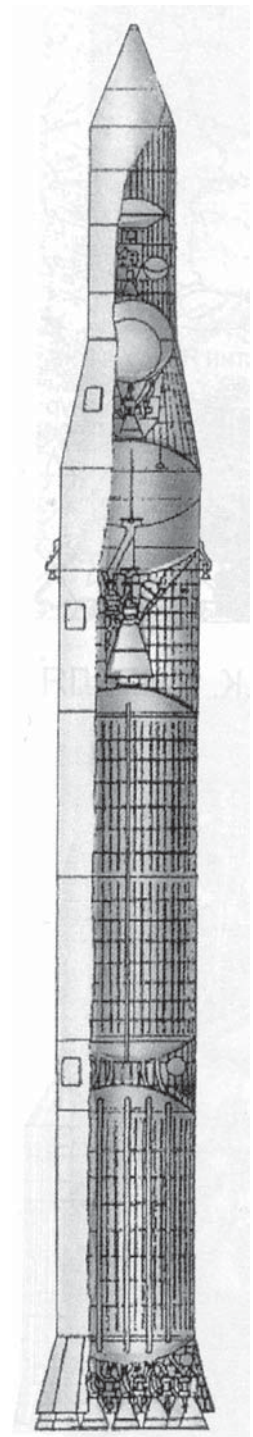


Fig. 15 Four-stage "monoblock" version of the R-56.

TABLE 4: Key Parameters of the “Monoblock” R-56 (2nd Half of 1963)*.

Lift-off mass	1421 t
Stage 1	
Modules	1
Engines	16 x RD-253
Propellants	N2O4/UDMH
Thrust (sea-level)	148 t
Specific impulse (sea-level)	285 s
Total amount of combustion chambers	16
Combined thrust	2368 t
Stage 2	
Modules	1
Engine	1 x RD-254 (main engine) 1 x RD-? (control engine)
Propellants	N2O4/UDMH
Thrust (vacuum)	172.3 t (main engine) 30 t (control engine)
Specific impulse (vacuum)	325 s (main engine)
Total amount of combustion chambers	1 (main engine) 4 (control engine)
Combined thrust	202.3 t
Stage 3	
Modules	1
Engines	1 x 8D418 (main engine) 1 x RD-? (control engine)
Propellants	N2O4/UDMH
Thrust (vacuum)	50 t (main engine) 5.5 t (control engine)
Specific impulse (vacuum)	327 s (main engine)
Total amount of combustion chambers	1 (main engine) 4 (control engine)
Combined thrust	55.5 t
Stage 4	
Modules	1
Engines	1 x RD-280
Propellants	N2O4/hydrazine-50
Thrust (vacuum)	12 t
Specific impulse (vacuum)	350 s
Total amount of combustion chambers	1
Combined thrust	12 t

*Data taken from S. Konyukhov, “*Rakety i kosmicheskiye apparaty konstruktorskogo byuro Yuzhnoye*”, p.98; S. Konyukhov, O. Drobakhin and V. Pashchenko, “Little-Known Project of Super-Heavy Space rocket”.

velopment for the UR-500 (although one of the earlier designs had called for fixed engines with smaller auxiliary engines to provide steering).

The second stage had a single fixed RD-254 engine and a four-chamber 30 ton thrust control engine for steering. In order to reduce the mass and size of the rocket, the second stage had a common bulkhead between the oxidizer and fuel tanks.

The third stage, referred to by Russian sources as the “orbital stage”, was powered by a non-restartable, single-chamber engine with a thrust of 50 tons as well as a 5.5

ton thrust, four-chamber control engine. In one document Glushko referred to the engine as the 8D418, an N2O4/UDMH engine developed by his own bureau [69]. This engine has not been described anywhere else. The performance was very similar to the engine unit used on the third stage of the Proton rocket (the RD-0212, which consists of a single RD-0213 (thrust 59.3 tons) and a four-chamber RD-0214 control engine (thrust 3.15 tons)), developed by the OKB-154 of Semyon Kosberg. However, there are no indications that Kosberg’s bureau co-operated with Glushko’s OKB-456 on the 8D418.

The fourth stage was equipped with a single engine that could be ignited four times. Developed by Glushko’s bureau, this engine was known as the RD-280 (or 8D725). It is first mentioned in Glushko’s published correspondence in May 1963, where it is described as an engine burning N2O4/UDMH with a specific impulse of 325 s and is included in a list of upper stage engines with a thrust of between 10 and 12 tons. Sometime in late 1963/early 1964 it switched from UDMH to a fuel known as “hydrazine-50”, which was similar, but not identical to the “aerazine-50” fuel developed in the United States for the Titan-2 ICBM (a combination of 50% UDMH and 50% pure hydrazine). This resulted in a higher specific impulse (345s-350s) and a thrust of 12 tons. In June 1964 Glushko made an unsuccessful attempt to propose it as an upper stage engine for the N-1 [70]. Finally, a government decree on 28 April 1965 would call for developing the 8D725 as an upper stage engine for an orbital version of the R-36 in 1965-1968, but it was later dropped in favour of a third stage engine built in-house by the Yangel bureau [71]. By the end of the decade experiments with hydrazine-50 showed that it was prone to “local explosions” and it was eventually never used [72].

Separation of the first and second stages was to occur after ignition of the second stage control engine. After separation, the first stage would be pulled away by small solid-fuel motors, followed by ignition of the second-stage main engine. The separation systems between the other stages and between the final stage and payload also used small solid-fuel motors. The first stage oxidizer tank was pressurized by “air dynamic pressure” and beginning at T+1m47s additional pressurization was achieved by injecting small amounts of UDMH fuel into the tank. The first, second and third-stage fuel tanks were pressurized by special gas generators and the fourth-stage tanks by what are described as bottles with compressed gas.

The rocket had an autonomous control system designed by NII-94 (chief designer Viktor Kuznetsov) and OKB-692 (chief designer Vladimir Sergeyev; established by Yangel in Kharkov in 1959 to develop the control system for the R-16 missile). The system made it possi-

ble to launch the rocket in any azimuth from a non-rotatable launch table and also allowed the rocket to fulfill its mission objectives in case one of the first-stage engines failed. The third and fourth stages had their own, combined control system. An escape rocket with solid-fuel engines and parachute systems could be mounted on the rocket to safely pull spacecraft away from the rocket in case of a pad emergency or a first stage failure. The system would be jettisoned from the launch vehicle after first-stage separation [73].

The payload capacity of the monoblock version of the R-56 for a variety of orbits and trajectories is given in Table 5. One source claims that the design of the monoblock booster was further optimized, with the final version having a launch mass of 1300 tons [74].

TABLE 5: *Payload Capacity of the “Monoblock” R-56*.*

Orbit/Trajectory	Payload (tons)
200 km circular/90°	40
200 km circular/49°	46.1
500 km circular/90°	21
500 km circular/49°	25
36,000 km/0°	6.5
to the Moon	12.6
into orbit around the Moon	7.0
soft landing on the Moon	2.8
to Mars	8.0
into orbit around Mars	3.0
to the surface of Mars	up to 2.0
to Venus	9.0
into orbit around Venus	2.0
to the surface of Venus	1.5
trajectories perpendicular to the ecliptic (altitudes of resp. 10 million, 20 million and 50 million km)	11.0/8.7/1.6

*As given in S. Konyukhov, *“Rakety i kosmicheskiye apparaty konstruktorskogo byuro Yuzhnoye”*, pp. 98-99.

6.5 Improved Versions of the R-56

Even as the design of the “standard” R-56 was still being hammered out, specialists also began looking at the possibility of significantly increasing the rocket’s payload capacity in the future. One possibility they explored was to turn the first stage into a cluster of two or three 6.5 m modules [75]. Since that would have doubled or tripled the amount of RD-253 engines on the first stage, the hope probably was that such versions of the R-56 would employ the 600-ton thrust RD-270 engine. They would also likely have required the construction of one or more new launch pads. The

option to build a clustered first stage (with up to six modules) was briefly revisited when attempts were made to revive the R-56 in the late 1960s (see section 9).

Another idea to improve the rocket’s performance was to use high-energy upper stages. One plan was to outfit the second and third stages with liquid oxygen/liquid hydrogen engines, virtually doubling the rocket’s capacity [76]. Although studies of such cryogenic engines were underway at the OKB-2 Isayev bureau and the OKB-165 Lyulka bureau in the early 1960s, there are no indications that any of the engines were seriously considered for use on the R-56.

An even more promising propellant combination was liquid fluorine/liquid ammonia. Fluorine offers higher specific impulses and is denser than liquid oxygen, but is a very toxic and corrosive substance. Glushko’s OKB-456 had begun work on a liquid fluorine engine in accordance with a party/government decree of 20 March 1958 (No. 344-167). Originally, the Glushko bureau considered an open combustion cycle for the engine, but in early 1960 decided to switch to a staged combustion cycle. In the decree the engine (RD-303 or 8D21) had not been linked to a particular rocket and Glushko made unsuccessful attempts in 1960 to advertise it to both Korolyov (for use on an R-7 type rocket) and Yangel (for use on the R-20 and probably also the RK-100).

With the rocket designers showing little enthusiasm for the use of fluorine, the GKOT decided to intervene. On 23 November 1962 it ordered Yangel’s bureau to issue design requirements for such an engine to OKB-456 and also to come up with a draft design for an upper stage carrying such an engine that would be part of a “heavy rocket” (presumably the R-56). Apparently, it took a while for Yangel to respond to the order, because it wasn’t until 1965 that Glushko’s bureau started working on the engine. Although it had the same vacuum thrust (10 tons) and specific impulse (400 s) as the RD-303 and was also non-restartable, it differed slightly from the RD-303 in order to meet Yangel’s requirements and was therefore designated RD-302 (or 11D13F). The engine reportedly accumulated 40,000 seconds of firing time in 309 test firings. Ironically, all this happened *after* the official cancellation of the R-56 in June 1964. In a bizarre case of inefficient bureaucracy, Glushko’s bureau ended up testing an engine destined for a rocket that had been scrapped. As one source concluded: *“Apparently, the [GKOT] order and [Yangel’s] design requirements were more the result of the diplomatic talent of V.P. Glushko than the urgent need for using such an engine”* [77]. Possibly, the test firing programme did provide important data for the RD-301, a *restartable* liquid fluorine/liquid ammonia engine concurrently under development for

Chelomei's alternative lunar landing project (UR-700/LK-700) and later reoriented as an upper stage engine for the Proton rocket, although it ultimately never flew.

Yet another idea for the more distant future appears to have been to install a nuclear rocket engine on the rocket. In a letter on 11 October 1962 to Boris Komissarov, the head of the 7th Chief Directorate of GKOT, Valentin Glushko mentioned a plan to perform research in 1963 on a nuclear engine with a thrust of 30 to 40 tons to be installed on an upper stage of a "heavy rocket" of Yangel's OKB-586. OKB-456 is known to have begun studies of a nuclear engine in that thrust range earlier in 1962. Called the RD-405, it was a so-called solid-core nuclear engine burning liquid hydrogen with a specific impulse of 900-950 s. When Korolyov presented the N-1 "draft design" to a commission of experts in July 1962, he said that mounting such an engine on the third stage of the N-1 would increase its payload capacity by 60 tons. However, the use of nuclear engines on future versions of the N-1 was not mentioned in a key party/government decree on the N-1 issued on 24 September 1962, which may very well have prompted Glushko to turn to Yangel. In the letter to Komissarov, containing proposals for a new government/party decree on nuclear engines, he said that he had personally agreed with Yangel to finish the "draft design" for a nuclear-powered upper stage in December 1963. However, in 1963 OKB-456 abandoned solid-core nuclear engines (leaving that work to Bondaryuk's OKB-670) and shifted its focus to more complex gas-core nuclear engines [78].

6.6 Transporting the R-56 to the Launch Site

The penalty that had to be paid for constructing the monoblock version in one piece at the factory was that unconventional means had to be found to transport the rocket to the launch site. No aircraft available at the time was capable of flying the rocket's elements to any of the cosmodromes, leaving transportation by water as the only option.

Launches were considered from all three Soviet cosmodromes, Baikonur, Plesetsk and Kapustin Yar. In all scenarios, the vehicle would first be moved by road from Factory No. 586 to a newly constructed berth located at the point where the Sura River flows into the Dnepr south of Dnepropetrovsk. There it would be loaded onto a modified self-propelled barge known as ST-600. In order to reach Kapustin Yar, the rocket would follow a route that took it through the Black Sea, the Sea of Azov, the Volga-Don Channel and the Volga, arriving in Volgograd for the final trip by road to the launch site (total distance: 2030 km, of which only 30 km was by road).

Transportation to Baikonur would initially be via the

same route, but now the rocket would follow the Volga all the way to its mouth in the Caspian Sea, travel along the coastline and then enter the Ural river to reach the town of Inderborskiy, where it would be offloaded for the final trip to the cosmodrome (total distance: 4270 km, 1200 km by road).

The route to Plesetsk would have been even longer: via the Volga river, the Rybinsk Reservoir, the Sukhona and Severnaya Dvina rivers (total distance: 6200 km, 100 km by road). Transportation by road would occur with an 8x8 truck known as MAZ-537. Kapustin Yar, the cosmodrome closest to the factory, was the preferred location from a transportation standpoint, although it was not as elaborately equipped as the two other launch sites.

After arriving at the launch site, the completely assembled rocket would be placed in a specially constructed storage facility while the payload underwent preparations in a separate building nearby. In another departure from standard Soviet practice, the rocket and payload would be moved to the launch pad separately and mated only after the rocket had been erected on the pad. The R-56 launch complex was to consist of two pads with a single mobile service tower that could be moved to any of the two pads over interconnecting rails. Completely enclosing the launch vehicle, the tower would protect the rocket against the elements and maintain normal temperatures inside. Service platforms inside the tower would provide access to various parts of the launch vehicle. Only after fuelling of the launch vehicle would the tower be rolled back to parking position. Each pad had a flame deflector system that would divert the engine exhaust away from the vehicle through a single exhaust duct. A bunker containing launch equipment would be situated under the launch table [79].

6.7 Earth-Orbital Missions for the R-56

As noted earlier, the R-56 was presumably conceived primarily as an intercontinental ballistic missile or global missile to carry 50 to 100-megaton warheads or less powerful multiple warheads, but that particular application of the rocket seems to have moved to the background relatively soon, giving way to its role as a space booster.

The development of payloads for the R-56 was the responsibility of a dedicated "space department" set up within OKB-586 in July 1962. Called "Complex 8", it was headed by Vyacheslav M. Kovtunencko, one of Yangel's deputies. In July 1965 Complex 8 was reorganized as KB-3, essentially a small design bureau within OKB-586 specialized in the development of satellites. At the time, Kovtunencko's team was primarily occupied with design-

ing small military and scientific satellites (the “DS” series) for launch by Yangel’s “Kosmos” boosters, but at least some time was set aside for working on projects related to the R-56.

Military tasks envisioned for the R-56 were to place into orbit heavy military space stations, reconnaissance satellites, communications satellites, inspection and “killer” satellites. Military research institutes reportedly came to the conclusion that the launch of such spacecraft would require a booster capable of placing 40 to 50 tons into 200-300 km orbits. Particular emphasis was placed on the capability of placing satellites into either geostationary orbits or inclined geosynchronous orbits with a ground track resembling a distorted figure eight. Studies performed at OKB-586 showed that such satellites would have to weigh 2 to 3 tons if they were to remain active for up to two years and 5 to 6 tons if they were to remain operational longer, for instance by carrying a nuclear reactor for power supply [80]. Kovtunenkov’s Complex 8 drew up preliminary plans for a universal geostationary/geosynchronous platform called Zvezda (“Star”) that could serve as a bus not only for communications satellites, but other types of satellites as well [81].

6.8 Lunar Missions for the R-56

Histories of the Yangel design bureau reveal that the rocket was also designed to play a key role in the Soviet Union’s manned lunar programme, not so much to compete with the N-1 in putting cosmonauts on the Moon, but to pave the way for such missions and support them once they were launched. As one OKB-586 veteran puts it: *“The R-56 ... was to solve some of the tasks in the ... exploration of the Moon, namely to support the lunar expedition in its preparatory phase and after landing on the lunar surface, assuming that the task of landing on the Moon would be conducted on the basis of the N-1 carrier”* [82].

The lunar missions described for the R-56 by the Yangel bureau histories are:

- manned circumlunar missions and large-scale photography of the lunar surface
- the creation of automatic stations, forming a “lunar patrol service”
- delivery of supplies for manned lunar expeditions

The automatic probes would have investigated the trajectory to the Moon, tested soft-landing techniques, studied the environment around the Moon and the physical properties of the lunar surface itself [83]. At one point, the schedule was for the R-56 to fly its maiden mission in the first half of 1966 and launch an unmanned lunar landing mission in 1967 [84]. OKB-586’s Complex 8 studied unmanned lunar probes under the project name

“Selena”, but this work never advanced very far and no further details have ever been revealed [85]. Also among the intended missions for the R-56 was the launch of unmanned interplanetary probes.

As mentioned above, launching manned circumlunar missions was considered as a goal from the outset and a task that the R-56 was perfectly capable of fulfilling. The objective of actually *landing* on the Moon was almost certainly in the back of Yangel’s mind when he proposed the “big R-56” in March 1962, but an idea that became much less attractive after only the “small R-56” with its 30-ton payload capacity was approved for further study in the 16 April 1962 decree. A lunar landing mission would have required the launch of *multiple* R-56 rockets to assemble the Moon ship in orbit, complicating the mission scenario.

This was probably not the only reason that piloted lunar landing missions are unlikely to have been high on the priority list of R-56 missions in the 1962-1963 timeframe. Yangel’s bureau did not have any expertise in developing piloted spacecraft and there is no indication whatsoever that it ever had the intention of doing so. The primary task of OKB-586 was to develop efficient intercontinental ballistic missiles to achieve strategic parity with the United States. These efforts far overshadowed the bureau’s space-related activities, which remained limited to a number of boosters based on those missiles and a series of small scientific and military satellites. Therefore, if the R-56 was going to be involved in manned lunar expeditions, OKB-586 would have to limit itself to building the rocket, while the task of building the manned vehicles would have to be entrusted to the only design bureau with experience in the field, namely Korolyov’s OKB-1. However, as Glushko pointed out in his letter to Ustinov and Smirnov on 12 March 1962, OKB-1 showed little if any enthusiasm for such co-operation, preferring to build both the rocket and its payloads all by itself. Part of the reason for that undoubtedly was that Korolyov was wary of using toxic storable propellants in a man-rated rocket.

More importantly, piloted lunar exploration did not become an official objective for the Soviet space programme until the release of a party/government decree in August 1964, more than three years after President Kennedy’s announcement of the goal to put American astronauts on the Moon before the end of the decade. The June 1960 decree that sanctioned the N-1 project did not mention lunar landing missions as a specific goal for the rocket, merely stating that it should be capable of orbiting a 60 to 80 ton “interplanetary ship” [86]. The following years Korolyov struggled to muster support for the rocket from the military community, which was sceptical of its military applications. The next key decree on the

N-1 (No. 1022-439), released on 24 September 1962, again did not specify the payloads to be carried aloft by the N-1, merely calling for the Academy of Sciences and the Ministry of Defence to formulate proposals for high-priority payloads within a three-month timeframe [87].

In November 1962, after having analyzed the N-1 draft design, GUKOS (the “space branch” of the Strategic Rocket Forces) concluded that the N-1 would have no real military value and despite further efforts by Korolyov to come up with military missions for the rocket, the military remained unconvinced [88]. The Academy of Sciences was slower to respond to the decree. In December 1962 it approved a plan for space exploration for 1963-1964 that centred on the use of automatic probes and virtually ignored the N-1. It wasn't until August 1963, apparently under significant pressure from Korolyov, that the Academy came up with a space exploration plan for 1965-1975 that placed significant emphasis on human exploration of the Moon and the planets and assigned a significant role to Korolyov's OKB-1 and its N-1 rocket. Actually, the plan largely reflected the proposals for the scientific uses of the N-1 that OKB-1 itself had presented to the Academy in April 1963.

The plan envisaged that the field of lunar exploration would be virtually monopolized by OKB-1's rockets and spacecraft:

- Project Ye-6: automatic soft-landing probes using OKB-1's R-7 based 8K78 “Molniya” rocket (the project saw its first mission in 1963, but would not achieve success until February 1966 with the landing of Luna-9)
- Project L-1: required six launches of OKB-1's 11A511 “Soyuz” rocket to send a 5.1-ton two-man vehicle (7K) on a mission around the Moon. 7K was the progenitor of the Earth-orbiting Soyuz spacecraft.
- Project L-2: required six launches of the 11A511 to land a 5-ton rover on the Moon
- Project L-3: required three launches of the N-1 and one of the 11A511 to land a 21-ton manned vehicle on the Moon
- Project L-4: required a single N-1 launch to place a 12-ton manned vehicle into lunar orbit for long-duration photography missions
- Project L-5: required a single N-1 launch to place a 5.5-ton rover on the lunar surface, allowing cosmonauts to cover large distances on the Moon.

While the plan paid significant attention to human lunar exploration, it did not list any aspect of scientific space exploration as the highest-priority objective and merely summed up a series of partly overlapping space science and exploration proposals put forward by various design bureaus. In a letter to the GKOT on 23 September 1963 Korolyov, not surprisingly, voiced his support for the Academy plan, but also urged that manned lunar explo-

ration should clearly be announced as the primary objective and criticized some of the duplication of effort in the plan.

In Korolyov's vision, OKB-1 would have a monopoly in the field of manned Earth-orbital missions and automatic and manned lunar and interplanetary missions, while Yangel's bureau would build “scientific satellites” and Chelomei's bureau satellites that would permanently monitor the Sun, the ionosphere and the radiation environment. He even insisted on adding various other tasks to OKB-1's plate, including automatic lunar stations that would conduct routine observations of the lunar environment and also perform astrophysical observations, studies of cosmic rays, the Sun and the Earth, typically the sort of missions that could be handled by a single R-56. In short, if Korolyov was going to have his way, there would not be any room for OKB-586 in lunar exploration, neither in spacecraft nor in rocket development [89].

There is reason to believe that the decision to increase the payload capacity of the R-56, made at a VPK meeting chaired by Leonid Smirnov in August 1963, was related to the Academy plan. Smirnov is known to have received a copy of the plan, presumably in early August 1963, and the beefed-up R-56 was said to be “the optimal rocket for the programme of 1965-1975”, possibly indicating a link with the Academy plan for the same period [90]. Whether that also pertained to the manned lunar programme is questionable. Even with its increased payload capacity (46 tons to a 200 km, 49° inclination orbit), the R-56 would have provided little advantage over the N-1 with its 75-ton payload capacity.

Even the N-1 itself at this stage was not powerful enough to launch a lunar landing mission in one go. As noted above, in mid-1963 Korolyov's L-3 plan relied on the principle of Earth Orbit Rendezvous (EOR). It would see the launch of three N-1 rockets to assemble and fuel in Earth orbit a 200 ton complex consisting of an Earth departure stage, trajectory correction stage, lunar descent stage and lunar ascent stage. A single N-1 could launch all the elements of the complex, but two more N-1 launches would be needed to deliver the propellant needed to get to the Moon. The crew would fly separately to the complex in a Soyuz-type vehicle launched by the 11A511 rocket. They would land on the Moon without first entering lunar orbit and then perform a “direct ascent” back to Earth. Assuming the same profile would have to be flown with the R-56, at least four and possibly five launches would have been needed, not to mention the fact that the L-3 complex had been tailored to fly on the N-1 and modifying it to fit an EOR scheme using the R-56 would have been easier said than done. It made little sense to move from an already complex EOR plan to an even trickier one, the more so because at that point the Soviet

Union (as well as the United States for that matter) had no experience whatsoever in docking spacecraft, one of the motives that had prompted Korolyov to move directly from R-7 based rockets to the N-1 in 1960 [91]. The first docking exercises were supposed to be performed in the framework of the circumlunar L-1 project, which was approved as “the Soyuz complex” by a party/government decree on 3 December 1963.

The only manned lunar mission where the R-56 would have offered an advantage over OKB-1’s boosters was the L-1 lunar fly-around mission, which could have been accomplished with a single R-56 rather than six Soyuz-type boosters. When it came to actually placing a manned vehicle into *lunar orbit* (L-4), the N-1 provided almost twice more capacity than the R-56 (12 tons versus 7 tons). Preliminary plans for manned circumlunar missions were concurrently being drawn up by Chelomei’s OKB-52, but all these relied on the bureau’s own UR-500K “Proton” rocket.

Sometime in 1963, NII-88, the GKOT’s leading R&D institute (renamed TsNIIMash in 1967), conducted a comparative analysis of the N-1, the UR-500, R-56 and the L-1 “Soyuz complex” and recommended the L-3 type Earth Orbit Rendezvous scenario proposed by OKB-1, also noting that the N-1 could play an important role in follow-on piloted expeditions to the Moon and the planets [92].

Despite the support for his L-3 EOR scheme from both the Academy of Sciences and NII-88, Korolyov was still struggling to get official approval for his lunar plans. An important step in this process was a meeting with Nikita Khrushchov on 17 March 1964, also attended by Vasilii Mishin (one of Korolyov’s deputies, who became his successor in 1966), Viktor Kuznetsov (head of NII-944, the lead design bureau for gyroscopes) and Nikolai Pilyugin (head of NII AP, the lead design bureau for guidance systems). During the meeting Khrushchov generally supported the idea of intensifying work on the piloted lunar programme, but showed little enthusiasm for Korolyov’s plans to equip the N-1 with liquid oxygen/liquid hydrogen engines and nuclear engines and to test docking techniques in orbit [93]. This left Korolyov with a dilemma as far as the mission profile was concerned: without testing docking techniques in Earth orbit, the EOR scheme was not realistic, and without the new engines a single-launch profile with a significant payload was not possible either. The meeting seems to have moved OKB-1 in the direction of a single-launch scenario with Lunar Orbit Rendezvous (LOR) that would be achieved by uprating the payload capacity of the N-1 using the existing LOX/kerosene engines, even though that would significantly reduce the mass of the lunar complex as compared to the 1963 EOR scheme [94].

6.9 Yangel Proposes to Unite Forces

By the end of 1963 the Soviet manned lunar programme was in a state of complete disarray. Not only was it still awaiting official government and Communist Party approval, three design bureaus were offering boosters for similar missions. Without a strong, central body (like NASA in the United States) to coordinate space projects, the internal struggle between the chief designers was threatening to lead to a wasteful duplication of effort and stifle a programme for which there was only flimsy high-level support.

Perhaps not so much blinded by naked ambition and personal ego as Korolyov and Chelomei, Yangel came up with a bold proposal in early 1964 for a division of labour that would unite the efforts of the three design bureaus. Actually, the idea to share tasks between OKB-586 and OKB-1 already seems to have circulated in early 1962 after the conception of the “big R-56”, but now Yangel tabled a more elaborate plan. He made his move during a meeting of the VPK in March 1964. The exact date of the meeting is not known and therefore it is impossible to establish if it came before or after Korolyov’s meeting with Khrushchov that same month and was in any way influenced by its outcome [95]. Little is known about the exact details of Yangel’s proposal other than that he put forward the idea to concentrate the development of rockets at his own OKB-586, give Korolyov’s OKB-1 the exclusive right to build piloted spacecraft and turn over the development of “automatic and interplanetary stations” to Chelomei’s OKB-52 [96].

It is not clear if Yangel’s proposal was specifically aimed at lunar and deep space exploration or also extended to Earth-orbiting missions. At any rate, when it came to the lunar programme, the idea apparently was that Chelomei would build the unmanned probes to scout the lunar surface in preparation for manned expeditions and that OKB-1 would build the piloted vehicles to orbit the Moon and eventually land on it. OKB-586 would provide the rockets needed to launch *all* those missions. A single R-56 was perfectly capable of launching a manned circumlunar mission and this was one of the goals that Yangel had been aiming for with the R-56 from the outset. A manned lunar landing mission was beyond the capability of a single R-56, but with the shift from the massive 200-ton lunar complex to a 90-ton class lunar payload launched by a single N-1, the use of the R-56 was becoming more realistic.

Theoretically, only two R-56 launches would now be needed to fly the same mission. Unfortunately, almost nothing has been revealed about the exact mission scenario that Yangel had in mind, although it clearly would have stretched the capability of even two R-56 rockets. One source claims that the idea was to launch the (unmanned) lunar lander and

(manned) lunar orbiting vehicle with two separate R-56 rockets and dock them in lunar orbit, where one cosmonaut would transfer to the lander and descend to the lunar surface [97]. As mentioned earlier, OKB-586 designers were also looking at growth versions of the R-56 that would eventually have given it a capability similar to or even better than the N-1 and allowed it to launch manned lunar landing missions in one go.

6.10 The Downfall of the R-56

Yangel's initiative to unite forces was an unprecedented move, but it came too late. Although many reacted positively to the proposal, he was told that too much time and resources had already been invested into the projects of Korolyov and Chelomei to turn back the clock. Vyacheslav Kovtunenkov, the chief of OKB-586's space department, later recalled: *"We suggested that [OKB-586] do the launcher – Yangel's bureau had very substantial experience building ballistic missile launchers- and Korolyov work on the L-3. But Korolyov was not enthusiastic about this and the idea came to nothing. The mistake of the N-1/L-3 programme was that they worked a lot on the launcher but not enough on the space segment. So it turned out that the space part was much heavier than it should have been and the launch vehicle was not big enough, it had to be beefed up"* [98]. R-56 chief designer Stanislav Konyukhov later attributed the decision in favour of the N-1 to the lack of docking experience: *"Korolyov's project envisaged a mission to the Moon with a single launch, our project required two launches with a docking of modules in orbit. I had to defend the project but at the time no one believed that it was possible to dock spacecraft ...and therefore the N-1 project was chosen"* [99].

Before returning to Dnepropetrovsk, Yangel reportedly had a meeting with Dmitriy Ustinov, who at this time was First Deputy Chairman of the Council of Ministers (the Soviet government). Ustinov tried to console him with the following words: *"Why do you want to get involved in big space [projects]? Your missiles are in the forefront of the country's missile forces. As long as we are surrounded by imperialists and the Soviet Union exists, your design bureau will always have work"* [100].

With his proposal rejected, the future of the R-56 looked bleaker than ever, but Yangel insisted that the project should undergo a thorough government analysis before any decisions were made on its ultimate fate. After all, the R-56 had been designed for much more than lunar missions alone. Later in March 1964 GKOT Chairman Sergei Zverev and VPK Deputy Chairman Georgiy Pashkov visited OKB-586. One account of the visit suggests that Zverev and Pashkov had been sent to Dnepropetrovsk to "find reasons" to shut down the R-56

project. Yangel pointed out the advantages of the R-56 over the N-1, stressing among other things that unlike the N-1 engines the R-56's RD-253 engines were already undergoing test firings for their use on the UR-500. Zverev and Pashkov expressed concern over the use of toxic propellants on a man-rated rocket, but Yangel countered this argument by pointing out that the UR-500 was supposed to use exactly the same propellants. According to the account, *"both Zverev and Pashkov understood that Yangel had designed an interesting rocket, but that in the given situation no one would support it. Many would feel sorry for [Yangel], but no one would take the risk of countering the opinion that had formed in the Central Committee"* [101]. Another source says that Zverev and Pashkov ordered Yangel to stop preparations for starting R-56 production. By that time, construction had already begun of a huge building ("Object 100") to assemble the R-56 and roads near the factory were being adapted to allow the huge elements of the rocket to be transported to the Sura river for transport to one of the cosmodromes [102].

Even the visit of Zverev and Pashkov was not enough for Yangel to throw in the towel. With no official government decision on the fate of the R-56 made yet, he arranged a meeting with Leonid Brezhnev, who in his capacity as Central Committee Secretary for Defence Matters had been the *de facto* head of the Soviet space programme since June 1963 (Fig. 16). Brezhnev had already occupied the post from July 1957 to July 1960 before being temporarily relegated to the largely ceremonial function of Chairman of the Supreme Soviet (the Soviet parliament). Not only was Brezhnev an influential figure in the Soviet space programme, he was also a native of the Dnepropetrovsk region, the home base of OKB-586. Unfortunately, despite his close ties to Dnepropetrovsk, Brezhnev does not appear to have been sufficiently impressed by Yangel's presentation of the rocket to breathe new life into the project [103].

The fate of the R-56 was definitively sealed during a meeting of the VPK on 4 June 1964. Held at the premises of the Kremlin and chaired by Leonid Smirnov, the meeting was attended by several leading government and Communist Party officials, five chief designers (including Korolyov and Yangel) and the President of the Academy of Sciences Mstislav Keldysh [104]. The decision to cancel the R-56 was formalized in a new party and government decree (No. 524-215, called "On speeding up work on the N-1 complex") issued on 19 June 1964, which ordered to allocate additional funding to the N-1 in order to achieve a maiden launch in 1966.

7. A Role in Chelomei Boosters

Meanwhile, as a formal government decision on a Soviet



Fig. 16 Leonid Brezhnev.

manned lunar project was drawing closer, Valentin Glushko had been looking at new alternatives to the N-1 that would employ his engines. On 31 March 1964 he sent a letter to Chelomei, proposing a clustered rocket with storable propellants that would equal the payload capacity of the Saturn-5 (120 tons) [105]. Not only would it significantly outperform the N-1 with its 75-ton capacity, it also had a far smaller amount of engines than the N-1 and its individual modules could be completely built in the country's production facilities. Although Chelomei's OKB-52 would perform the role of what in the West would be called a "prime contractor", Glushko suggested a major role for Yangel's OKB-586 on the basis of its experience with the R-56.

Provisionally labelled UR-1000, the mammoth rocket would have a first stage configured similarly to that of the UR-500, but on a larger scale. It would consist of a central N₂O₄ oxidizer tank (diameter 6.5 m) with smaller UDMH fuel tanks (diameter 1.65 m) strapped around it. The stage would be powered by eight 600-ton thrust RD-270 engines, originally studied for the R-56. The second stage would carry either a single high-altitude version of the RD-270 or four RD-254 engines and the third stage (with a smaller diameter) the four engines of the Proton second stage (RD-0210/0211), developed by the OKB-154 of Semyon Kosberg. OKB-586's task would be to design the first two stages (based on technical requirements issued by OKB-52), while the aligned Factory No.586 would build both stages and their engines. The 6.5 meter tanks would be shipped to the cosmodrome by

water in the same fashion as the R-56 first and second stages, which had an identical diameter. OKB-52 would bear prime responsibility for the third stage and payloads, which would be constructed at the Khrunichev factory in Moscow.

It is not known if Yangel was aware of the letter and how Chelomei reacted to OKB-586's possible involvement in the project. The rocket clearly was an early version of what would become known as the UR-700. Actually, Chelomei himself had been drawing up preliminary plans for heavy-lift rockets with payload capacities of between 70 and 175 tons (among other things with nuclear engines) since 1962 [106]. These would have made it possible to perform lunar landings without intermediate dockings in Earth or lunar orbit. He first presented the UR-700 to the country's leadership when Khrushchov paid a visit to the Baikonur cosmodrome in September 1964 [107]. In October 1965 the Ministry of General Machine Building gave the go-ahead to draw up a "pre-draft design" for the UR-700, but in the end Yangel never became involved in the project. Not only may Chelomei have been against that idea, in its final design the UR-700 rocket modules had the same standard diameter as those of the UR-500 and no longer required OKB-586's expertise with the design and manufacture of 6.5 m modules. In Yangel's biography it is claimed that Chelomei did not bother to send details of the UR-700 design to OKB-586 and that Yangel had to send one of his specialists to the NII-88 R&D institute to "virtually illegally" study Chelomei's project. In his opinion the design was too complex, a conclusion reported by Yangel's deputy Budnik at a subsequent meeting where the UR-700 was on the agenda [108].

Yangel's biography also mentions another, much less known alternative to the N-1 that was put forward by Prokofiy Zubets, the chief designer of OKB-16 in Kazan. This design bureau was set up in December 1953 to design aircraft engines, but in 1959 branched out into solid-fuel motors for anti-aircraft and anti-missile missiles. In October 1963 it became a branch of Nikolai Kuznetsov's OKB-276. Zubets came up with a plan for a massive rocket using a new type of hybrid propellant (a combination of solid and liquid propellant). He turned to OKB-586 to study the proposal, but Yangel's experts concluded that the rocket would have to be 1.5 times heavier than the N-1 to give it the required performance and deemed the project unrealistic [109].

8. Yangel's Consolation Prize: The Blok-Ye

The official go-ahead for the Soviet manned lunar programme came in a landmark party and government decree on 3 August 1964 (No.655-268, "On work to study

the Moon and cosmic space”), which assigned the manned circumlunar programme to Chelomei’s OKB-52 (using the UR-500K/Proton rocket and LK-1 capsule) and the manned lunar landing project to Korolyov’s OKB-1 (using the N-1 and the L-3 payload). It was only now that lunar missions became the N-1’s official goal. The first manned circumlunar mission was to take place in 1966 or the first half of 1967, followed by a lunar landing in 1967-1968.

Korolyov’s plan was now to launch a manned lunar mission on a single N-1 using the Lunar Orbit Rendezvous profile. In order to achieve that goal, the first stage would have to be equipped with an additional six engines (bringing the total to 30), increasing the rocket’s payload capacity from 75 to 90 tons (Fig. 17). Comprising the L-3 payload were two new upper stages, the Blok-G (for translunar injection) and Blok-D (for lunar orbit insertion and initial descent to the lunar surface), as well as the LOK lunar orbiter and the LK lunar lander. A single cosmonaut would land on the lunar surface in the Lunar Module (LK), equipped with a descent/ascent engine (Blok-Ye) [110] (Fig. 18). His colleague would remain in lunar orbit aboard the Soyuz-derived Lunar Orbital Ship (LOK), which would use a powerful engine unit (Blok-I) to propel itself out of lunar orbit and carry out mid-course corrections on the way back to Earth.

Although the R-56 had been cancelled, OKB-586 would still get a piece of the lunar pie. The 19 June decree had tasked Yangel’s bureau and even Glushko’s OKB-456 with developing upper stages that would allow the rocket to launch manned lunar landing missions without intermediate dockings in Earth orbit [111]. VPK Chairman Leonid Smirnov had already called for involving the two organizations in the project in the wake of Korolyov’s meeting with Khrushchov on 17 March 1964 [112].

There were probably two reasons to farm out development of the L-3 propulsion systems to other design bureaus. Firstly, Korolyov’s team was on a very tight schedule to achieve a maiden N-1 launch in 1966 and was first and foremost preoccupied with the three-stage N-1 rocket itself, not to mention the lunar spacecraft. Secondly, some of the propulsion systems (particularly the Blok-Ye and Blok-I) would have to remain functional for several days, complicating the use of cryogenic liquid oxygen with its high boil-off rates. Therefore, it made more sense to use engines relying on storable propellants, just like NASA had decided to do with the Apollo Service Module and Lunar Module propulsion systems. Since OKB-1 had no expertise in the development of such engines, it was logical that the task would be entrusted to other design bureaus.

Although Korolyov and Glushko must barely have been on speaking terms as a result of their disagreements over

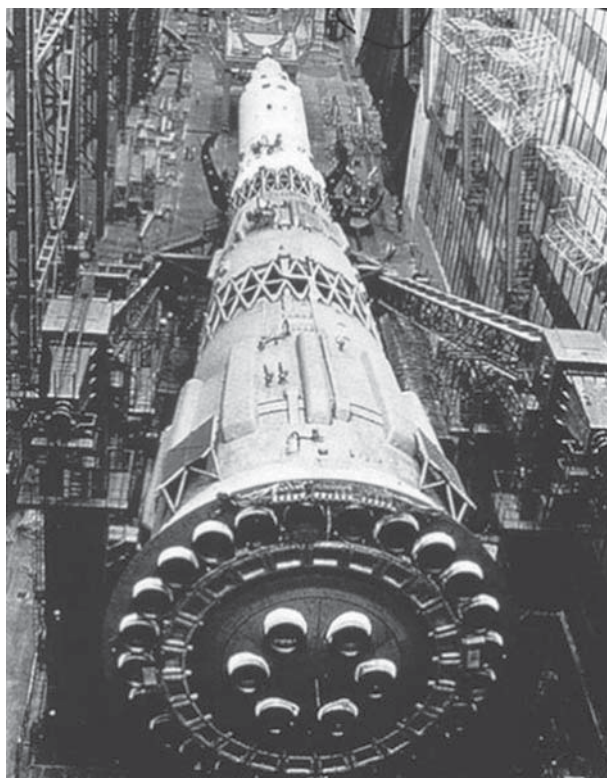


Fig. 17 The N-1 rocket in the assembly building.

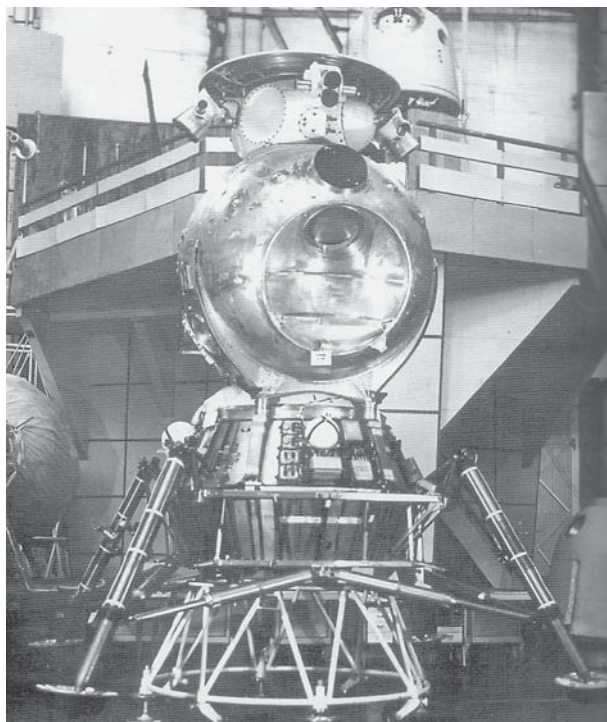


Fig. 18 The Soviet LK lunar lander.(source: RKK Energiya)

the propellant choice for the N-1, Glushko did suggest at least three different types of upper stage engines for the rocket in the June-August 1964 timeframe: the RD-303 (fluorine/ammonia), the RD-280 (N₂O₄/UDMH) and the RD-119 (LOX/UDMH) [113]. Even at this stage, Glushko adamantly continued to call for a version of the N-1 using *only* UDMH and nitrogen tetroxide (a version called “D-A”), a standpoint which he again defended during a meeting of chief designers convened by Korolyov on 23

June 1964. However, the majority of the attendees favoured a version that would use LOX/kerosene in all stages (the so-called “K” version), which would later be superseded by a version using liquid hydrogen in the third stage (the “V-3 version”) [114].

OKB-586 specialized in building missiles and not the engines that powered them, but an engine department (KB-4) had been set up at the bureau in 1958 to develop small steering engines for Yangel's intercontinental ballistic missiles and was considered to have the necessary expertise to build upper stage engines for the N-1. However, Korolyov would not find it easy to approach Yangel. The two had had little personal contact ever since Yangel had left NII-88 to head OKB-586 in 1954. Although there had been no direct cause for any major arguments between the two chief designers in the previous years, their strained relations were probably still the result of the frictions caused by Yangel's assignment as director of NII-88 back in 1952. Moreover, Korolyov may well have had a hard time accepting that Yangel had essentially won the “missile race” between the chief designers. Rather than contact Yangel himself, Korolyov first called Aleksandr Makarov, the head of OKB-586's production facility (Factory No. 586), to gauge Yangel's interest in taking part in the N-1/L-3 project. It took Makarov some effort to convince Yangel of the need to arrange a meeting with Korolyov, but in the end the OKB-1 chief designer was invited to Dnepropetrovsk in July 1964 and was joined by Georgiy Tyulin, the First Deputy Chairman of GKOT [115].

Sources differ on what exactly was discussed and decided at the meeting, which was attended by OKB-586's leading designers. One account suggests that OKB-586 was offered to build *all* the L-3 propulsion systems, not only those for the LK and LOK (Blok-Ye and Blok-I), but also those for the two upper stages (Blok-G and Blok-D), the idea evidently being that all would use storable propellants. In this version, a team of 24 OKB-586 specialists was subsequently sent to OKB-1 in August 1964 to explore the role that the design bureau could play in the project and remained there until March 1965. Shortly before they left, Yangel came down to Moscow and a final decision was made that OKB-586 would build only the Blok-Ye [116]. Yangel's first deputy Vasiliy Budnik reportedly wrote a letter to Korolyov in January 1965, saying OKB-586 would limit itself to the development of the Blok-Ye because of an overload of other work [117].

Yangel bureau veteran Boris Gubanov recalls that the decision to build only the Blok-Ye had already been made *before* Korolyov's visit following several weeks of internal debate at the design bureau on the level of co-operation in the N-1 project. In his account, Korolyov's visit was only intended to hammer out the details and OKB-586

was officially assigned to the Blok-Ye in the historical government and party decree of 3 August 1964. Subsequently, a team of OKB-586 was sent to OKB-1 to work out the details of the design [118]. At any rate, the “draft design” for the N-1/L-3 project was signed in December 1964 and approved by an expert commission in February 1965, indicating that the choice of design bureaus that would build the upper stages had been made by that time. The Blok-G would be powered by a LOX/kerosene engine built by Nikolai Kuznetsov's OKB-276, the Blok-D engine would also use LOX/kerosene and be developed in-house at OKB-1 and the LOK vehicle's propulsion system (Blok-I) would be built by the OKB-2 of Aleksei Isayev, which was the lead design bureau for spacecraft propulsion systems.

Relegated to a secondary role in the lunar programme, Yangel was reportedly never overly enthusiastic about the development of the Blok-Ye. Essentially, his design bureau had been asked to perform the role of what would be called a “subcontractor” in the West, a position that Yangel did not feel comfortable with. According to Yangel's official biography, he delegated virtually all work on the Blok-Ye to his deputies, not even bringing up the topic during design bureau meetings. Although Yangel did not in any way try to block the development of the Blok-Ye, he felt as if the project had been forced upon him from above and he had only agreed to get involved in it “because he placed the country's interests above his personal interests” [119]. Factory No. 586 chief Aleksandr Makarov claims he arranged another meeting between Yangel and Korolyov (attended only by himself) to discuss their differences, but after having exchanged what Makarov calls “meaningless phrases”, the two parted company after just thirty minutes, not having changed their viewpoints. It is said to have been the only eye-to-eye meeting between Korolyov and Yangel during their tenure as chief designer [120]. What exactly was discussed during the meeting is unknown, but Yangel may very well have suggested to revive the R-56.

9. Attempts to Revive the R-56

Evidently, Yangel had a hard time accepting the decision to cancel the R-56 and did not completely abandon the idea of resurrecting it. When a delegation of OKB-1 engineers visited Dnepropetrovsk to discuss progress on the LK lunar lander, he reportedly told them: *“Don't you get the impression that after the R-7 we are making a very sudden jump by creating the N-1 with a 100-ton payload? Our design bureau is prepared to build a medium-lift rocket which can place 40 to 50 tons into Earth orbit... Except for [flights to] the Moon it will be difficult to find a worthy use for such a massive and expensive rocket. Our rocket will be significantly cheaper and will have plenty of payloads”* [121].

It is now known that Yangel was still hoping to revive the R-56 as late as early 1969. At that stage, the rocket had retained its “monoblock” design, but by now development of the powerful RD-270 engine, already considered for use on the rocket in 1962-63, had advanced far enough for it to become the prime candidate to propel the first stage. The RD-270 had begun test firings in late 1967 and was also the engine eyed for the first stage of Chelomei’s UR-700 rocket. Four of them would be enough to provide the same thrust as a cluster of sixteen RD-253 engines, thereby significantly simplifying the design and making it less prone to failure. The second stage would still be equipped with a single RD-254 and together the two stages could place a 50-ton payload into low orbit. There was also a plan to add a third stage with a liquid fluorine/liquid hydrogen engine called RD-351 (thrust 25 tons) to increase the payload capacity to 75 tons. The combination of fluorine and liquid hydrogen offered very high specific impulses of up to 465 s. Development work on the RD-351 got underway at OKB-456 in 1966, but did not advance further than the “pre-draft design” stage [122].

This new version of the R-56 was mentioned by Glushko in correspondence to the Ministry of General Machine Building and the Central Committee in January 1969 as one in a series of steps to restore the Soviet Union’s pre-eminence in space now that the country was losing the lunar race with the United States. Glushko did not mention any specific payloads for the rocket, merely stating that a rocket of this class was needed to fill the big payload gap between the Proton and the N-1. In the longer run, by clustering three or six modules, phenomenal payload capacities of up to 225 tons and 450 tons could be reached [123]. All indications are that this latest proposal for a Yangel heavy booster also fell on deaf ears. Moreover, the testing of the RD-270, a key element of the revamped rocket, was not producing satisfactory results. All the 27 test firings conducted between October 1967 and July 1969 ended in some kind of failure before development of the engine was suspended in August 1969. On top of that, the UR-700, for which the engine was primarily being developed, had no future prospects now that the Soviet Union had definitively lost the lunar race with the landing of Apollo-11 in July 1969 [124].

The Blok-Ye eventually turned out to be Yangel’s first and only foray into the manned spaceflight arena. It consisted of a throttleable single-chamber engine (11D411/RD-858) and a two-chamber non-throttleable back-up engine (11D412/RD-859) and associated propellant tanks containing UDMH and nitrogen tetroxide (Fig. 19). The propulsion unit was successfully tested in three unmanned orbital test flights of the LK in 1970-1971 (Kosmos-379, 398, 434), but would never fulfill its primary role of landing Soviet cosmonauts on the Moon. In

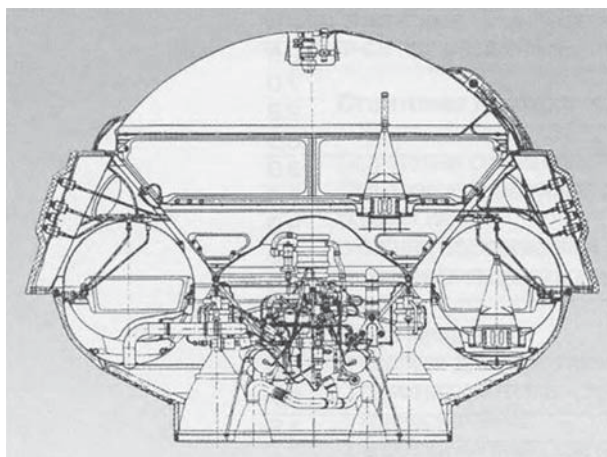


Fig. 19 Blok-Ye descent/ascent stage of the LK lunar lander.
(source: KB Yuzhnoye)

fact, the three LK test vehicles were the only lunar hardware of the L-3 complex ever to reach orbit. After four consecutive launch failures of the N-1 in 1969-1972, the Soviet manned lunar project was terminated. On a sidenote, KB Yuzhnoye made an unsuccessful attempt in 2005 to sell the Blok-Ye for use in NASA’s Constellation programme to return astronauts to the Moon [125].

10. Concluding Remarks

Ultimately, none of the three big boosters put forward by OKB-586 in the early 1960s moved further than the drawing boards. The RK-100 and R-46 were short-lived ideas that may have been suggested to Yangel by Glushko in an attempt to find a customer for some of his newly conceived rocket engines. Although OKB-586 did further work out those ideas, questions may be raised about Yangel’s level of commitment to both projects. At any rate, work on the RK-100 got underway too late for it to be included in the “big space plan” of June 1960 and the R-46 soon lost out against Chelomei’s UR-500.

The R-56 originated in late 1961, possibly in response to a call by Nikita Khrushchov to develop missiles capable of carrying 50 to 100 megaton warheads. Although Khrushchov reacted negatively to Yangel’s presentation of the project at a Defence Council meeting in February 1962, OKB-586 subsequently formulated a concept in which the rocket would evolve into a booster capable of orbiting 70 tons, rivalling the payload capacity of the N-1. However, a government decree in April 1962 approved only the R-56 with a 30-ton payload capacity for further study, meaning that it could not become a serious competitor to the N-1 in missions like landing Soviet cosmonauts on the Moon. Although ICBM and FOBS applications of the rocket seem to have moved into the background relatively soon, the Yangel bureau did come up with other possible missions for the R-56, including the launch of big military and communications satellites and flights in support of manned lunar landings.

In early 1964 Yangel took the bold initiative to split work on lunar projects (and possibly other projects as well) between the three major design bureaus (OKB-586, OKB-1, OKB-52), with OKB-586 providing rockets, OKB-1 restricting itself to manned vehicles and OKB-52 to unmanned payloads. The R-56 was easily capable of launching a manned circumlunar mission and, after its payload capacity was increased to 46 tons in August 1963, it could, theoretically at least, handle the L-3 mission scenario with a dual-launch scheme. Future, more powerful versions of the rocket could launch lunar landing missions in one go.

Without doubt, Yangel's proposed division of labour was a sound and cost-saving idea, but in early 1964 it was felt that too many resources had already been spent on the N-1 and Proton rockets to reverse course, certainly at a time when work on the Apollo programme had been underway for about three years. However, decision-makers had also failed to seize a similar and probably better opportunity two years earlier, when OKB-586 put forward the "big R-56" as a direct alternative to the N-1 and suggested that OKB-1 build only the payloads. At that point, even Apollo was only in its infancy, indicating that there were more basic obstacles to uniting the efforts of the design bureaus than America's lead in the Moon race. Among these were the lack of commitment to a manned lunar programme until August 1964, the absence of a single co-ordinating space agency like NASA in the United States, the military's disinterest in heavy-lift launch vehicles, the strained relations between the chief designers, their insatiable personal ambitions and, more specifically, Korolyov's aversion to rockets with toxic propellants.

Having said that, the realization that the R-56 could not play a significant role in the manned lunar programme must have been only one of the reasons that led to its cancellation in June 1964. After all, in April 1962 the rocket seems to have been approved with other missions in mind than lunar exploration alone. Two years on there may have been a growing feeling that the type of payloads it could launch would not materialize soon and that the Proton and N-1 rockets would satisfy the needs in the heavier payload classes for many years to come, with no other rocket required to fill the gap between the two. In the end, virtually all the main payloads envisaged for the R-56 (space stations, big communications satellites, lunar and planetary probes) were orbited by the Proton rocket and there was no urgent need for bigger payloads of this type. In the next two decades several more proposals were tabled for boosters with payload capacities between 30 and 60 tons (UR-530, 11K37, Groza, Energiya-M), but none of these were ever approved. Rockets of this type are too big for launching satellites, Earth-orbiting manned spacecraft and deep space probes and too

small for more ambitious goals like piloted missions to the Moon and planets. Even now, almost forty years later, no payloads in this mass range have ever been built anywhere in the world.

Purely on the technical side, the project would undoubtedly have benefited from Yangel's alliance with Glushko, who could have been counted on to deliver a reliable set of engines in a relatively short period of time. The most critical of those, the RD-253, was concurrently under development for the first stage of the Proton rocket and made its successful debut in July 1965, just three years after it had been conceived. Out of the thirteen failures that the Proton suffered in the 1960s, only three were due to first-stage malfunctions. While the Proton would have been an ideal test bed for the R-56, the safe simultaneous operation of sixteen RD-253 engines (compared to six on Proton) might eventually have proved more challenging than expected. Their replacement by a smaller cluster of RD-270 engines would not have been an option until much later, considering the development problems that the engine suffered.

Perhaps the biggest technical drawback of the R-56 project was the cumbersome and costly way to transport the rocket to the launch site (by water and road), necessitated by the decision to build the 6.5 m diameter rocket stages in one piece at the manufacturing plant in Dnepropetrovsk. The cheapest option in this respect would have been to launch the rocket from Kapustin Yar, but this was a relatively small cosmodrome with little supporting infrastructure that also offered fewer launch azimuths than Baikonur due to range safety restrictions. The route to Baikonur would have taken the rocket over no less than 1200 km of road, much of which would probably have had to be constructed specifically for that purpose. This method of transportation would also have been susceptible to such problems as harsh winter conditions. All in all, it is highly questionable if the benefits of assembling a "monoblock" rocket at the manufacturing plant outweighed the disadvantages of doing the same job *in situ* at the cosmodrome, allowing smaller sections of the stages to be transported to the cosmodrome via existing railroads (the solution chosen for the N-1). The high transportation costs for the R-56 may have been the single biggest *technical* reason for cancelling the rocket.

Finally, Yangel never garnered the political support needed to carry the R-56 through to fruition. There seems to have been a widespread feeling in government and Communist Party circles that Yangel should not engage in other projects than ICBMs, small launch vehicles and small satellites, leaving the big, eye-catching space projects to Korolyov and Chelomei. That attitude may at least partly have been attributable to traditional "Moscow chauvinism", because unlike the Moscow-based OKB-1

and OKB-52, OKB-586 was situated in the periphery of the Soviet Union (the “province” as Muscovites like to call it). The fact that two key figures in the management of the Soviet space programme (Leonid Brezhnev and Leonid Smirnov) had close ties to the Dnepropetrovsk region does not seem to have helped. One may wonder if things would have turned out differently if Brezhnev had become Soviet leader earlier than October 1964.

After 17 years at the helm of his design bureau, Yangel died on 25 October 1971 and was replaced as head of KB Yuzhnoye by Vladimir F. Utkin. Yuzhnoye’s main focus continued to be on ICBMs, derived launch vehicles

(Tsiklon) and relatively small scientific, Earth observations and military satellites. However, Yuzhnoye also built a dedicated two-stage space rocket called Zenit, which nowadays mainly flies in a three-stage configuration under the Sea Launch and Land Launch programmes. The rocket’s first stage also served as the strap-on booster for the massive Energiya rocket that launched the Soviet Union’s Buran space shuttle into orbit in 1988.

Acknowledgments

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44. S. Khrushchov, op. cit., pp.149-150. V. Ivkin, G. Sukhina, “*Zadacha osoboi gosudarstvennoi vazhnosti*”, ROSSPEN, Moscow, pp.646-647, 2010.
45. Yu. Baturin, op. cit., p.204.
46. S. Khrushchov, op. cit., pp.149-170.
47. The commission consisted of Dmitriy Ustinov (VPK Chairman), Leonid Smirnov (GKOT Chairman), Pyotr Dementyev (GKAT Chairman), Valeriy Kalmykov (Chairman of the State Committee for Radio-Electronics or GKET), Ivan Serbin (Chief of the Central Committee’s Defence Industries Department), Rodion Malinovskiy (Minister of Defence), Matvey Zakharov (Chief of the General Staff) and Kirill Moskalenko (Commander-in-Chief of the Strategic Rocket Forces). See: Yu. Baturin, op. cit., p.204.
48. “*Izbrannye raboty...*”, op. cit., pp.221-229.
49. Glushko apparently refers to the “big R-56” in a letter to the Chief of the 7th Directorate of GKOT (B. Komissarov) (copy sent to Yangel) on 19 February 1962. See: “*Izbrannye raboty...*”, op. cit., p.216.
50. It is not clear how Glushko arrived at these figures. By July 1962 the N-1 had a total of 36 engines (twenty-four on the first stage, eight on the second stages and four on the third stage). See: G. Vetrov, op. cit., p.376.
51. Letter by Glushko to Korolyov on 10 November 1961. See: “*Izbrannye raboty...*”, op. cit., pp.204-211.
52. G. Vetrov, op. cit., pp.358-359. The letter was sent to ten persons, seven of whom are known to have been members of the commission set up after the February 1962 Pitsunda meeting (Ustinov, Malinovskiy, Smirnov, Moskalenko, Serbin, Dementyev and Kalmykov). Note that in Russian literature the rocket is always designated N-II (with Roman numerals).
53. G. Yefremov, op. cit., p.158.
54. B. Gubanov, op. cit., p.140.
55. L. Andreyev and S. Konyukhov, “*Yangel: uroki i naslediyе*”, op. cit., pp.448-449.
56. S. Khrushchov, op. cit., p.413.
57. S. Konyukhov (ed.), “*Rakety i kosmicheskiye apparaty konstruktorskogo byuro Yuzhnoye*”, GKB Yuzhnoye, Dnepropetrovsk, p.96, 2000. Eventually, the first Soviet missile with multiple re-entry vehicles became the R-36P (NATO designation SS-9 Mod 4), development of which began in 1967.
58. A link between the influential Smirnov and the approval of the R-56 is implicitly suggested in: B. Chertok, “*Rakety i lyudi: lunnaya gonka*”, Mashinostroyeniye, Moscow, p.79, 1999.
59. S. Konyukhov, *Prizvany vremenem...*, op. cit.
60. I. Afanasyev, “Stanislav Konyukhov turns 70” (in Russian), *Novosti kosmonavtiki*, 6/2007, p.25; N. Mitrakhov, “S.N. Konyukhov: I certainly didn’t time my birthday to coincide with Cosmonautics Day” (in Russian), online at <http://www.nkau.gov.ua/nsau/newsnsau.nsf/PublicationU/9F5B9F001994ACBC22572BB004D220B?OpenDocument&Lang=U>. (Date Accessed 10 September 2010).
61. Letter by Glushko to M. Subbotin on 3 May 1965, see “*Izbrannye raboty...*”, op. cit., p.277. Note that in early correspondence Glushko only refers to the engine as 8D420 and the name RD-270 does not appear until April 1965. In an earlier letter dated 6 May 1963 Glushko used the designator RD-270 for an experimental upper stage engine burning nitrogen tetroxide and pentaboran. See: “*Izbrannye raboty...*”, op. cit., p.250.
62. “*Izbrannye raboty...*”, op. cit., pp.231-234.
63. “The liquid rocket engine RD-270 (8D420)” (in Russian), on-line at <http://www.lpre.de/energomash/RD-270/index.htm>. (Date Accessed 10 September 2010)

64. B. Katorgin, op. cit., p.199, 469; "The liquid rocket engine RD-270 (8D420)", op. cit.
65. B. Gubanov, op. cit., p.140; S. Konyukhov, "*Rakety i kosmicheskiye apparaty konstruktorskogo byuro Yuzhnoye*", op. cit., p.96. This may have been part of a broader decree (No. 565-197) that also tasked OKB-586 with the development of the RT-20P mobile ICBM. See S. Konyukhov, "*Prizvany vremenem...*", op. cit.
66. B. Gubanov, op. cit., p.140.
67. Ibid, p.139.
68. A. Borisov, Yu. Zhuravin, "Alternative Moon" (in Russian), *Novosti kosmonavтики*, 7/1999, pp.72-73; V. Molodtsov, "*Pilotiruemye kosmicheskiye polyoty (kniga 2)*", 2002, online at <http://epizodsspace.airbase.ru/bibl/molodtsov/01/05-2.html>. (Date Accessed 10 September 2010).
69. Abstracts of a presentation made by Glushko at the GKOT on 18 July 1963. "*Izbrannye raboty...*", op. cit., p.261.
70. The 8D725 version with UDMH/N2O4 and a specific impulse of 325s is mentioned in letters by Glushko dated 6 May 1963 and 18 July 1963. See: "*Izbrannye raboty...*", p.250, 261. It is also quoted by Korolyov in a letter dated 30 September 1963. See: G. Vetrov, op. cit., p.431. The first known reference to the improved version with hydrazine-50 does not come until 15 June 1964, when Glushko proposed it to Korolyov as an upper stage engine for the N-1. See: "*Izbrannye raboty...*", op. cit., p.266. In a comparison of Russian and American engines in May 1965, Glushko describes aerazine-50 as providing less specific impulse than hydrazine-50 and having a freezing point of -7.3°C compared to about -60°C for hydrazine-50. See: "*Izbrannye raboty...*", p.282. At a technical meeting on 17 June 1969 he said hydrazine-50 consisted for 50 % of "hydrazine borine". See: "*Izbrannye raboty...*", p.328.
71. "Bulletin of declassified documents of federal state archives, nr. 7" (in Russian), online at http://www.rusarchives.ru/secret/bul7/arrangements_ap_1965.shtml, (Date Accessed 10 September 2010); B. Katorgin, op. cit., p.470.
72. Glushko described the problems during a technical meeting at his design bureau on 17 June 1969. See: "*Izbrannye raboty...*", pp.325-332.
73. R-56 description compiled from: S. Konyukhov, O. Drobakhin and V. Pashchenko, "Little-known project of super-heavy space rocket", 50th International Astronautical Congress, Amsterdam, The Netherlands, 1999. Paper No. IAA-99-IAA.2.3.02; S. Konyukhov, "*Rakety i kosmicheskiye apparaty...*", op. cit., pp.96-99; L. Andreyev, S. Konyukhov, "*Yangel: uroki i naslediyе*", op. cit., pp.448-450; S. Konyukhov, "*Prizvany vremenem...*", op. cit.
74. B. Gubanov, op. cit., pp.141-142. Note that in contrast to all other sources Gubanov says the monoblock R-56 had four RD-254 engines on the second stage rather than just one. For the original monoblock version with a lift-off weight of 1400 tons he gives the total thrust of the second stage as 614 tons (although the thrust for a single RD-254 is given as 172.3 tons) and for the final version with a lift-off mass of 1300 tons that value is 640 tons. According to Gubanov, the final version had a third stage with a single 172-ton thrust engine, indicating this was also the RD-254. The possibility cannot be excluded that Gubanov mixed up the data for the monoblock and polyblock versions of the R-56.
75. S. Konyukhov and L. Andreyev, "Big space unknown projects of M.K. Yangel", op. cit.; S. Konyukhov, O. Drobakhin and V. Pashchenko, op. cit.; S. Konyukhov, "*Rakety i kosmicheskiye apparaty...*", op. cit., p.96.
76. B. Gubanov, op. cit., p.142.
77. V. Rakhmanin and L. Sternin (ed.), "*Odnazhdy i navsegda*", Mashinostroyeniye, Moscow, p.551, 1998.
78. "*Izbrannye raboty...*", op. cit., pp.234-236, 242-245, 389; B. Katorgin, op. cit., p.162, 239; G. Vetrov, op. cit., p.366.
79. See [72]. A map in *Yangel: uroki i naslediyе* shows an alternative route to Baikonur: from the mouth of the Volga to the southeastern coast of the Caspian, through the Karakum desert along the Soviet-Iranian border, then via the Amu Darya river and the Aral Sea to the cosmodrome.
80. B. Gubanov, op. cit., pp.139-140
81. S. Konyukhov, "*Prizvany vremenem...*", op. cit.
82. B. Gubanov, op. cit., p.141.
83. V. Platonov, "Moonlit night over the Dnepr" (in Russian), *Zerkalo nedeli*, 3-9 August 1996, online at <http://www.zn.com.ua/3000/3150/7524/>. (Date Accessed 10 September 2010).
84. B. Gubanov, p.141.
85. S. Konyukhov, "*Prizvany vremenem...*", op. cit. Actually, this source calls the project "Selen", but *selen* is the Russian word for the chemical element selenium, while "Selena" is the Russian equivalent of "Selene", the Greek goddess of the Moon.
86. Yu. Baturin, op. cit., p.96. The following years OKB-1 worked on a "Heavy Interplanetary Ship" (TMK) that would send cosmonauts to Mars. One former OKB-1 employee claims that in the first half of the 1960s the N-1 was mainly designed with that goal in mind. See: V. Bugrov, "*Marsianskiy proyekt S.P. Korolyova*", Russkiye Vityazi, Moscow, 2007.
87. Yu. Baturin, op. cit., pp.236-238.
88. B. Gubanov, op. cit., p.125.
89. G. Vetrov, op. cit., p.381, 410-426.
90. G. Vetrov, op. cit., p.424; B. Gubanov, op. cit., p.140.
91. V. Polyachenko, op. cit., p.69.
92. M. Yevtifiyev, "The first Soviet Mars projects" (in Russian), *Novosti kosmonavтики*, 4/2004, p.61; M. Yevtifiyev, "From the history of work on Mars projects at TsNIlmash" (in Russian), 29th Academic Readings on Cosmonautics, January-February 2005, abstracts online at <http://www.ihst.ru/personal/akm/6t29.htm>, (Date Accessed 10 September 2010); B. Chertok, "*Rakety i lyudi: lunnaya gonka*", op. cit., p.86. Yevtifiyev says the study was related to space exploration in general, while Chertok links it specifically to the lunar programme.
93. G. Vetrov, op. cit., pp.442-444, 458, 691-692; B. Chertok, "*Rakety i lyudi: lunnaya gonka*", op. cit., p.82.
94. G. Vetrov, p.458.
95. There was a major VPK meeting on 13 March 1964, but this is only known to have discussed failures in the Luna and Venera programmes and set timelines for the newly approved Voskhod programme. There are no indications that the manned lunar programme was on the agenda that day or that Yangel was present. See: B. Chertok, "*Rakety i lyudi: goryachiye dni kholodnoi voyny*", Mashinostroyeniye, Moscow, p.288, 1997.
96. The March 1964 VPK meeting is described in: S. Konyukhov and L. Andreyev, "Big space unknown projects of M.K. Yangel", op. cit.; L. Andreyev and S. Konyukhov, "*Yangel: uroki i naslediyе*", op. cit., pp.452-455; S. Konyukhov, "*Prizvany vremenem...*", op. cit.
97. A. Borisov and Yu. Zhuravin, op. cit., p.73.
98. J. Harford, "*Korolev*", John Wiley & Sons, New York, p.272, 1997.
99. N. Mitrahkov, op. cit.
100. B. Gubanov, op. cit., p.142.
101. V. Platonov, op. cit.
102. B. Gubanov, op. cit., p.142.
103. Ibid.
104. Ibid, p.128. The government officials present at the meeting were G. Pashkov (VPK Deputy Chairman), S. Zverev (GKOT Chairman), P. Dementiyev (GKAT Chairman) and V. Kalmykov (GKET Chairman). The Central Committee was represented by I. Serbin (chief of the Committee's Defence Industries Department). Other chief designers present besides Korolyov and Yangel were V. Sergeyev (OKB-692), N. Pilyugin (NII AP) and M. Ryazanskiy (NII-885). The possibility cannot be excluded that Yangel's proposal for a division of labour in the lunar programme was made at

- the 4 June 1964 VPK meeting rather than in March 1964.
105. "Izbrannye raboty...", op. cit., pp.263-265.
 106. I. Yevteyev, "Operezhaya vremya", Bioinformservis, Moscow, p.465, 1999; G. Yefremov, op. cit., p.113.
 107. S. Khrushchov, op. cit., pp.492-494.
 108. L. Andreyev and S. Konyukhov, "Yangel: uroki i naslediye", op. cit., p.463. The authors may refer to a 26 August 1965 VPK meeting that discussed lunar matters and where Budnik is known to have been present. See: G. Vetrov, op. cit., pp.475-488.
 109. L. Andreyev and S. Konyukhov, "Yangel: uroki i naslediye", op. cit., p.463. OKB-16 later became KB Soyuz. It is not to be confused with the OKB-16 of Aleksandr Nudelman, now KB Tochnogo Mashinostroyeniya ("Tochmash").
 110. The descent/ascent stage was designated with the sixth letter of the Russian alphabet, which is usually transliterated as "Ye". This is not to be confused with the 30th letter, transliterated as "E".
 111. G. Vetrov, op. cit., p.692; B. Gubanov, op. cit., p.128.
 112. G. Vetrov, op. cit., p.455.
 113. Glushko letters to Korolyov on 15 June 1964 and 21 August 1964 (the latter CC to Yangel). See: "Izbrannye raboty...", pp.266-268.
 114. G. Vetrov, op. cit., pp.458-460.
 115. B. Gubanov, op. cit., p.181.
 116. L. Andreyev and S. Konyukhov, op. cit., pp.455-462.
 117. A. Siddiqi, "Challenge to Apollo", Washington, NASA, p.492, 2000.
 118. B. Gubanov, op. cit., pp.181-182. The decision to assign the Blok-Ye to OKB-586 is also linked to the 3 August 1964 decree in S. Konyukhov, "Prizvany vremenem...". However, the text of the decree has now been declassified and it merely says OKB-1 has been tasked with the development of the N-1/L-3 complex, without mentioning the design bureaus assigned to specific components of the system. Possibly, this was mentioned in a hitherto unpublished supplement to the decree or a VPK order that followed the decree.
 119. L. Andreyev and S. Konyukhov, "Yangel: uroki i naslediye", op. cit., pp.462-464.
 120. Ibid, p.459.
 121. V. Filin, "Vospominaniya o lunnom korable", Izdatelstvo Kultura, Moscow, p.38, 1992.
 122. B. Katorgin, op. cit., p.201.
 123. "Izbrannye raboty...", p.314-315, 318. Note that at this point Glushko did not mention a name for the rocket.
 124. B. Katorgin, op. cit., p.110-111, 200, 323-324.
 125. C. Lardier, "Youjnoe propose un moteur pour la Lune", *Air et Cosmos*, p.104, 10 June 2005.

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