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FIRST TO THE MOON

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The Soviet Union was the first nation to send probes into deep space, achieving three of the most important 'firsts' in the history of space exploration, i.e. the first spacecraft to reach escape velocity; the first artificial object to reach the surface of another celestial body, and the first spacecraft to take pictures of the farside of the Moon. As with all other Soviet space projects of the time, only successes were announced in public. In recent years, the flood of information on early Soviet space programmes has allowed historians to rewrite the "official history" of their early space achievements. Certainly the most important progenitor of the early Soviet space effort was Chief Designer Sergey P. Korolev of the Experimental Design Bureau No. 1 (OKB-1) based in Kaliningard (now called Korolev) near Moscow. Along with his old comrade-in-arms Mikhail K. Tikhonravov at the Scientific Research Institute No. 4 (NII-4), Korolev was the personal force behind the emergence and spectacular successes of the Soviet space programme in the late 1950s and early 1960s.

1. THE OBJECT YE

In all the documents sent to the Soviet government by Korolev and Tikhonravov in the early and mid-1950s, two themes stand out: missions to the Moon and piloted flight into space. As early as 1954, in a landmark document on artificial satellites, Tikhonravov had written about he "problems of reaching the Moon" as a definite goal for the future. Korolev himself pursued this option through the ensuing years, clearly underlying his ultimate motivations for the early Soviet space programme. In February 1956, Tikhonravov participated in a well-publicised conference at the Leningrad State University to discuss issues relating to the physics of the Moon and the planets [1]. The first public pronouncement on the possibilities of lunar flight, however, came two months later in April during the All-Union Conference on Rocket Research into the Upper Layers of the Atmosphere held under the auspices of the USSR Academy of Sciences. Concluding his long oral presentation, Korolev told his audience:

> It is also a real task to prepare the flight of a rocket to the Moon and back from the Moon. The simplest way to solve this problem is to launch a probe from an Earth satellite orbit. At the same time it is possible to perform such a flight directly from the Earth. It would be more difficult to return to Earth the equipment from the probe or rocket, which has been launched toward the Moon. My statements here on this subject should not be considered long-term prospects. Yes, these are prospects, but real ones. They are matters of the not too distant future [2].

Preliminary work on this topic did not begin until November 1956, soon after Tikhonravov's group had been transferred from the military NII-4 to Korolev's OKB-1 as the new Department No. 9. This department went though some restructuring in the following year, when, on 8 March, it was reorganised as the "planning department for development of space apparatus", i.e. its focus was narrowed exclusively to space exploration, a significant event that in retrospect signalled the beginning or the Design Bureau's gravitation from missiles to spacecraft [3]. Within a month, Tikhonravov's group produced the first preliminary technical document on lunar and piloted space exploration entitled "A Project Research Plan for the Creation of Piloted Satellites and Automatic Spacecraft for Lunar Exploration" [4]. This report, authored six months before the launch of the first Sputnik and a month before the first launch attempt of the R-7, laid the necessary technical basis for further studies during the year, although it appears that the intensive work on the R-7 ICBM as well as the first Sputniks may have precluded any serious design work.

Design research on lunar probes, still notably in the absence of any governmental action on the matter, only began at the end of 1957 following the hysteria and excitement over the early Sputniks, Brimming with confidence in the abilities of his organisation, Korolev established three new design groups under Tikhonravov in December 1957

(1) for automatic lunar spacecraft

(2) for piloted spacecraft; and

(3) for communications satellites.

The section for lunar missions was headed Gleb Yu Maksimov, an alumni of Tikhonravov's early 1950s studies on artificial satellite who had hitherto specialised in computations of ballistic trajectories [5]. With Maksimov's team beginning their research, Korolev took the opportunity to place the issue to the Soviet leadership. As in the case of the first satellites, the push for lunar projects came once again from below without any governmental proposals for continuing the new space programme. One wonders if there would indeed have been a programme at the time if it had not been for Korolev. The Chief Designer was well aware of Military-Industrial Commission Chairman Ustinov's view on lunar exploration. As one Soviet journalist put it, "Ustinov did not need the Moon" [6].

Allied with the quiet and reticent but powerful USSR Academy of Sciences Vice-President Mstislav V. Keldysh, Korolev took the matter directly to First Secretary of the Central Committee of the Communist Party Nikita S. Khrushchev. In a letter to the Central Committee entitled "On the Launches of Rockets to the Moon" dated 28 January 1958, Korolev and Keldysh explained their two major goals in the lunar programme:

(1) A hard impact on the surface of the visible side of the Moon. An explosion, visible from the Earth would be carried out on impact. One or several initial launches could be carried out without explosives, but with telemetry equipment, which would register the rocket's trajectory and its impact on the lunar surface.

(2) Circumlunar flight with the taking of pictures of the lunar far side. The pictures would be transmitted by television equipment when the rocket would return to the Earth's vicinity. Return to Earth of observed materials appears to be a more difficult goal, and its solution we think would be possible only in the future [7].

Khrushchev, then basking in the glory of the prior successes in space, was quick to agree, no doubt recognising in Korolev's works a perfect demonstration of the advantages of the Soviet system. By the time that governmental approval was received on 20 March 1958, Maksimov's department had emerged with a detailed plan for four different variants of a lunar probe designated the Object Ye, the letters 'A', 'B', 'V', 'G' and 'D' having been used by other payloads of the R-7 [8]. The four versions of the new lunar spacecraft were described in a document signed by Korolev in early 1958 and included the following general characteristics:

Ye-1 (170 kilograms)
no orientation system
designed for lunar impact
radio-telemetry and thermal systems
five scientific instruments

Ye-2 (280 kilograms)
Orientation system
designed to take picture of the lunar far-side
programmed devices and thermal systems.
Yenisey-1
photographic camera with:
two lenses of 200 and 500 mm focal length
an automatic developing device
a TV device for transforming images to electric pulses
six scientific instruments

Ye-3 (400 kilograms)
no orientation system
designed for lunar impact
radio-telemetry and thermal systems
nuclear or conventional explosive to detonate upon impact or at altitude
scientific instruments

Ye-5 (280 kilograms)
same as the Ye-2 for photographing the farside of the Moon except:
different tracking, sending, and telemetry systems
different type of TV photographic system
a photo-camera with a single lens of 750 mm focal length
no lunar acquisition orientation system
optical scanning retrieval system for taking photographs of all planets within the field of vision of the system (60°) [9].

Based on early ballistic computations, the OKB-1 had already prepared a detailed schedule in December 1957 for the Object Ye exploration programme. Launches were to begin with the Ye-1 in August-September 1958, continuing with the Ye-2 and/or Ye-5 in October-November 1958 [10]. It was a typically ambitious plan which left less than a year to develop a completely new spacecraft, orientation system, launch vehicle, TV system, and ground communications network.

Clearly, much of the haste was related to concurrent US Air Force and Army plans to launch lunar probes by the summer of 1958 [11]. Contrary to conventional wisdom, it was not the Soviet Party leadership which advocated or called for Soviet pre-eminence in space at this early stage, but Korolev himself who was actualising his intense thirst to claim 'firsts' in the new arena of space exploration. Perhaps, as some of his biographers have suggested, it was also a psychological race against his chief rival, Wernher von Braun, whose achievements were well-known within the secret Soviet missile industry.

Work on the four lunar Object Ye variants began in late 1957 but the actual designs for the spacecraft evolved over the course of the following year. From the outset, Maksimov's group at the OKB-1 planned to have some sort of mechanism to locate the lunar spacecraft optically in deep space. The proposal eventually adopted was to create an artificial comet. The plan was to install an instrument in the core stage of he booster which would vaporise one kilogram of natrium during the outbound flight to the Moon, thus creating a cloud of natrium particles. Since the natrium clouds reflected in a very narrow spectrum, it would be possible to identify the cloud in relatively bright skies [12]. A particularly interesting aspect of the initial lunar probes was the means to ascertain conclusively the occurrence of lunar impact. For a brief period, the OKB-1 considered using a small nuclear explosive on the Ye-3 class probe which would detonate upon impact. A similar proposal had also emerged in the United States but Korolev himself appears to have been reluctant to go that route. Consultations with nuclear physicist Academician Yakov B. Zeldovich indicated that even if a nuclear device was used, the explosion would not be visible since there was no lunar atmosphere. A conventional explosive was also considered for studying the lunar soil content via spectral analysis of hot gases created by the blast. The engineers working on the problem soon realised that there would be intractable problems separating the spectra of the explosion from the soil. Eventually, in early 1958, the Ye-3 explosion variant was completely abandoned [13].

2. THE BOOSTER

Work on the lunar probes commenced concurrently with efforts to develop a new upper stage for the basic R-7 missile for the lunar missions. The two basic R-7 variants used for launching satellites, the 8K71 and the 8A91, could at best lift 1,400 kilograms into low-Earth orbit. In order to satisfy the immediate requirements of launching lunar probes and piloted spacecraft, an increase of three-fold over 1,400 kilograms was required which would allow the attainment of escape velocity for the Ye class lunar probes.

Proposals for building a new third stage for the basic R-7 booster were tabled in the summer of 1957, and work was begun soon after on two unrelated engines, one at Korolev's OKB-1 and one at Glushko's OKB-456, for possible use as upper stage engines [15]. By the end of 1957, the Council of Chief Designers had finalised plans for two new modifications of the R-7, the 8K72 and the 8K73 boosters. Both were to use the basic 8K71 R-7 ICBM as the core plus strap-on combination.

At the centre of the decision to develop two different launch vehicles was a minor rift between Chief Designers Korolev and Glushko, an altercation which in less than five years would evolve into the most acrimonious and infamous battle within the Soviet space programme. When plans for upper stage engines for the R-7 were originally drawn up in mid-1957, it was assumed that any new engine would be fuelled by the same combination of propellants as the booster proper, i.e. liquid oxygen (LOX) and kerosene. Glushko, however, had been impressed by a new synthetic propellant named unsymmerical dimethyl hydrazine (UDMH) developed for the first time in the USSR by the State institute for Applied Chemistry. According the Institute's data, the new component promised higher energy characteristics than the traditional LOX-kerosene combination. In a clear indication of his interests, in 1958 Glushko began the development of four new engines using UDMH, three in combination with nitrogen-derived oxidisers and the fourth in combination with LOX. It was the latter engine, the RD-109 with a vacuum thrust of 10.36 tons which he intended to offer for use on the 8K73 lunar rocket.

Korolev was not happy with this decision. His primary concern was clearly time and it was his belief that Glushko would be unable to design, develop and test the first Soviet rocket engine for work in vacuum with a completely new propellant combination in the given time, i.e. by late 1958. Despite entreaties to retain the LOX-kerosene combination, Glushko pursued work on the RD-109 engine. In this case, Korolev proved to be right. The tests of the engine were not finished in 1958, nor in 1959 and the same year, the Council of Chief Designers formally abandoned any plans to develop the 8K73 lunar launch vehicle [16].

Luckily for Korolev, there had been a second option, a small 5.04 ton thrust engine named the RD-0105 which was being developed in his own Design Bureau. Engineers under Mikhail V. Melnikov at the OKB-1 had already developed the small steering thrusters for the R-7 first stage engines whose performance characteristics could be scaled to match those needed for an upper stage. Korolev, still needing a turbopump to complete the engine, was saved by the help of a new entrant to the space programme. In 1957 he had been impressed by a report on the creation of a new restartable LOX-kerosene rocket engine developed in Voronezh at an aviation design organisation, the OKB-154, headed by Chief Designer Semyon A. Kosberg [17]. The 54 year old Kosberg had little interest in space or rocketry in general, content in his place in the aviation sector, but was eventually swayed by Korolev's persuasive arguments to collaborate with him on a new rocket engine capable of firing in vacuum. Thus Korolev and Kosberg signed a Memorandum of Understanding at Kaliningrad on 10 February 1958 which called for the design, development and delivery of the new RD-0105 engine in time for the first lunar attempts [18]. The cooperation with an 'outsider' was a slap in Glushko's face but it worked in Korolev's favour. Combining a turbopump from Kosberg's organisation with thrusters from Melnikov's group, the two Design Bureaux produced the RD-0105 engine in just nine months, ready for flight by August 1958. It was the first Soviet liquid-propellant rocket engine designed for use in vacuum.

3. THE CONTROL CENTRE

There was clearly a requirement for a new control centre with capabilities to track signals as weak as 0.1 microwatts in order to communicate and control all lunar and interplanetary spacecraft. Due to the shortage of time, the Council of Chief Designers opted to create a temporary control centre on the Koshka Mountain near the city of Simeiz in Crimea at the existing facilities of a branch of the Crimean Observatory and the Physical Institute of the USSR Academy of Sciences [19]. This facility was incorporated into the huge Command-Measurement Complex created in support of the Object D satellite in 1956-58.

Responsibility of creating the multi-functional long-range radio systems with the capability of receiving scientific and housekeeping telemetry from the lunar spacecraft fell on the shoulders Chief Designer Mikhail S. Ryazanskiy of the NII-885. One of the lesser known members of the Council of Chief Designers, Ryazanskiy had spent the early 1950s in a bureaucratic position in the Ministry of Armaments, but had returned to his beloved design job as the Chief Designer of Radio Control Systems having said that "administrative work is not for me". Ryazanskiy, one of the few Chief Designers who had actually earned the Soviet equivalent of a PhD for his scientific work, and his Deputy Yevgeniy Ya Boguslavskiy, oversaw the development and design of the radio-control and tracking systems at the new centre in Crimea in conformance with the radio systems on board the lunar probes. Beginning the fall of 1958, personnel from the military's tracking network began arriving at the site to rehearse for the impending lunar missions. Boguslavskiy, as one of the heads of the centre, was instrumental in bringing the facility to a nominal stage of readiness by 27 September [21]. Training sessions in October and November prepared all the controllers for the final assault on the Moon.

Despite the remarkable successes in creating the RD-0105 engine and the new centre at Crimea, there were major delays in the development of the 8K72 booster as a whole which had cumulative effects on the lunar probe programme. Although the lunar impact missions remained on schedule for late 1958, the farside photography missions were eventually delayed to a later time.

4. LUNAR IMPACT

The launch of the very first Soviet lunar probe was timed to respond to concurrent US plans. A series of Ye-1 lunar impact probes were prepared in the summer of 1958 to compete with three Pioneer spacecraft set for launch by the US Air Force Ballistic Missile Division and two to be launched by the US Army. It was well-known that the first outbound American lunar probe was set for 17 August 1958. Seeing a chance to be pre-empted, Korolev moved his first launch to the day after. Since the Soviet probe would fly a shorter trajectory, it would reach the Moon prior to the American spacecraft. The Air Force's Pioneer probe, however, exploded 77 seconds after lift-off so Korolev cancelled his own launch, erring on the side of caution.

There were, in fact, serious problems with the R-7 main engines as well as malfunctions during the pre-launch preparations which caused great concern among the Council of Chief Designers.

The same booster was moved to the pad again in mid-September after the requisite tests had eliminated the problems and readied for launch again. On board was the first of the Ye-1 probes designed to impact on the lunar surface. The 33.5 metre tall 8K72 booster lifted off from site 1 at Tyura-Tam on 23 September 1958 but only 87 seconds into the flight the vehicle disintegrated [23]. Following this failure, there were numerous major problems in preparing the second vehicle and the engineers and ground crews involved found themselves severely taxed, some even collapsing from physical exhaustion. There was immense pressure from Korolev to move the second spacecraft to the pad, timed once again to pre-empt an American attempt on the Moon. On 11 October, the Pioneer-1 probe lifted off from Cape Canaveral on the Air Force's Thor Able I booster. The launch was announced over a loud speaker at Tyura-Tam as ground crews were preparing the second Ye-1 spacecraft. Korolev, perhaps to raise morale, assembled all

Soviet Lunar Probe Launches (1958-60)

Ye-1 Lunar Impact launches

Probe	Variant	Serial No.	Launch Time	Launch Date	Launcher & No.
-	Ye-1	n1	-	Sep 23 1958	8K72 nb1-3
-	Ye-1	n2	-	Oct 12 1958	8K72 nb1-4
-	Ye-1	n3	-	Dec 4 1958	8K72 nb1-5
Luna-1	Ye-1	n4	1941:25	Jan 2 1959	8K72 nb1-6
-	Ye-1A	n5	-	Jun 18 1959	8K72 nIZ-7
Luna-2	Ye-1A	n6	0939:26	Sep 12 1959	8K72 nIZ-7b

Ye-2 Lunar Farside Photography Launches

Probe	Variant	Serial No.	Launch Time	Launch Date	Launcher & No.
Luna-3	Ye-2A	n1	-	Oct 4 1959	8K72 nI1-8

Ye-3 Lunar Farside Photography Launches

Probe	Variant	Serial No.	Launch Time	Launch Date	Launcher & No.
-	Ye-3 or Ye-2F	n1	1806:42	Apr 15 1960	8K72 nI1-9
-	Ye-3 or Ye-2F	n2	-	Apr 19 1960	8K82 NL1-9a

Sources
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2. Timothy Varfolomeyev, "Soviet Rocketry that Conquered Space: Part 3: Lunar Launchings for Impact and Photography", ***Spaceflight*, 38**, pp.206-208, June 1996.
3. B.Ye. Chertok, Rakety i lyudi: Fili Podlipki Tyuratam (Moscow: Mashinostroyeniye, 1996).

Note: Launch times are in Moscow Time.

personnel and advised them to "shake off their sleepiness and fatigue, drink some tea, and work as hard as they could for a couple of hours more" [24]. He assured those present that the Soviet probe would reach the Moon prior to Pioneer-1 due to the fact that the Ye-1 object was to be launched against the rotation of the Moon, while the US probe was heading in the direction of the Moon. Soon after, news was received at Tyura-Tam that a third stage failure had thwarted the mission of Pioneer-1. Engineers, naturally buoyed by a chance to pre-empt the US space programme, worked through the night for a launch the following day. The 8K72 booster lifted off successfully exactly on time on 12 October but after 104 seconds of operation the rocket once again exploded, covering the launch area with debris [25].

A special search-and-rescue team was assembled to gather all the debris near the launch area in order for OKB-1 engineers to determine the cause of the failure. This phase was apparently fraught with difficulties since the exact location of impact was still unknown at the time. The group of search workers had to endure severe cold temperatures at night in the semiarid plains of Kazakhstan. Food and water rations were also very scarce and had to be trucked in from far. In some cases, the military conscripts even had to hunt for food.

Eventually, all the fragments from the crash were photographed, collected, catalogued and returned to engineers at Tyura-Tam, and Korolev initiated a prolonged period of research to determine the causes of the two failures. A large commission headed by Academy of Sciences Corresponding Member Boris N. Petrov was established, composed of representatives from the OKB-1, the OKB-456, the NII-1 and Keldysh's Department of Applied Mathematics of the Academy's Mathematics Institute. The commission eventually ascertained that with the addition of the new upper stage, longitudinal resonant vibrations in oxidiser pipes of the strapon boosters had arisen which effectively tore the boosters apart.

The search for a solution to the recurrent problem was exacerbated by another feud between Korolev and Glushko, each refusing to concede that their respective organisations might be the ones to blame for the failures. A solution was recommended by engineers which involved the placing of a buffer in the oxidiser pipeline which would change the frequency of oscillation of the strapons [26].

The third Ye-1 vehicle was then assembled and launched on 4 December. This third time, at T+245 seconds into the flight, thrust levels on the core stage abruptly dropped by 70% and then cut off altogether. The booster stack eventually broke up upon re-entry into the atmosphere [27]. Coincidentally, Pioneer 3, launched just two days later, also failed to reach the required velocity to travel to the Moon, although a maximum altitude of 102,322 kilometres was achieved providing good data on high altitude radiation belts around the Earth [28]. By the end of 1958, all six lunar attempts, four US and three Soviet, had failed to achieve any of their primary objectives.

The problem with the third launch was quickly traced to the failure of a pressurised seal cooling in vacuum conditions and necessary compensatory work undertaken. Korolev's goal was to launch the probe by 31 December as a celebration of the new year. Along with Ryazanskiy, Pilyugin and Keldysh, he returned to Tyura-Tam on 20 December in a gloomy mood. As the new year approached, more and more problems cropped up in the booster and the payload. Ryazanskiy's engineers were having serious difficulties with the probe's radio control systems and stayed ensconced in the assembly building day and night trying to make Korolev's deadline. Ryazanskiy himself was being vague in reply to Korolev's constant inquiries. The temperature meanwhile, dropped to -30°C (-22°F) cracking open heating pipes in the local hostels.

On the morning of New Year's Eve, a problem was found in the booster's radio-control system which necessitated the replacement of the offending unit. The launch would have to be postponed. One of the range chiefs finally implored Korolev to allow the serving of alcohol despite the latter's adamant rule for its prohibition during any launch preparations. The Chief Designer, in a desultory mood, finally gave in, saying, "To hell with it. . . Give it away!" [29]. Korolev himself did not drink at all that night and woke up early the next morning to observe the preparations for launch, set for 2 January.

The countdown proceeded without any further incident and the fourth Ye-1 probe was successfully launched on time at 1941 hours 25 seconds Moscow Time on 2 January 1959. The probe lifted off gracefully and headed straight for outer space. This time, the booster worked like clock-work and the spacecraft was set on an escape trajectory becoming the first human-made object to reach escape velocity. The 361.3 kilogram probe, called the 'Cosmic Rocket' in the Soviet press, was a spherical object made from an aluminium-magnesium alloy about the size of the first Sputnik. Mounted on the external surface were four rod antennae, a central rod with a magnetometer, two proton traps and two piezoelectric detectors of meteoric particles. The main pressurised body contained radio equipment for controlling the trajectory and transmitting scientific data, a telegraph transmitter of variable duration and five scientific instruments for the investigation of the following:

(1) the gas component of interplanetary matter in the Sun's corpuscular radiation;

(2) the magnetic fields of the Moon and the Earth;

(3) meteoric particles and photons in cosmic radiation;

(4) heavy nucleii in primary cosmic radiation; and

(5) variations in cosmic ray intensity [30].

The primary goal of the mission was, of course, lunar impact, but preliminary data received at the new control centre at Crimea suggested that the trajectory of the vehicle was less than perfect. After confirmation was received that the probe would indeed miss the Moon, the mood turned gloomy. There was much finger pointing between various specialists as it became clear that the problem was a result of human error in calibrating a direction finder. The one kilogram of natrium was successfully released on 3 January at a distance of 113,000 kilometres from the Earth and was photographed by Soviet astronomers. The probe eventually passed by the Moon at a distance of 6,400 kilometres about 34 hours following launch [31]. Contact was maintained for a remarkable 62 hours as the spacecraft eventually became the first object to enter solar orbit.

The flight of the Cosmic Rocket (retroactively designated Luna-1) was an important mission not only for the engineers involved but also because it was the first Soviet space flight which tested the nerves of the Party's propaganda apparatus. Faced with the prospect of admitting the failure of a Soviet space mission, Mikhail A. Suslov, the country's 'chief ideologist' did not waver in his policy: there had not been a failure and nor would there ever be a failure in the Soviet space programme [32].

Thus newspapers such as Pravda and Krasnaya zvezda were forced to lie about the true intentions of the Cosmic Rocket, repeatedly reminding readers that the goal of the mission had been merely to fly into solar orbit. Some journalists even named the spacecraft, Mechta, the Russian word for 'dream'. It was a precedent which set in stone the manner in which the controlled Soviet press would report the events of the Soviet space programme in the following thirty years. Korolev, while displeased with the blatant hysteria over a failure in the programme, did not do much to prevent the spreading of the lie. The obscuring of the truth was merely taken as another accepted standard of conduct at the time. And he was, of course, astute enough to realise that the press reports had given a favourable sheen to one of his failures and it was hard to argue with that.

There was a gap of about six months before the next probe lifted off from Tyura-Tam. This delay was apparently related to continuing difficulties with the addition of a new upper stage on the basic R-7. There was even an attempt to freeze the programme at the level of the Military-Industrial Commission. Korolev made an impassioned speech at one of the Commission's meetings on the need to pursue the effort, conceding that there may have been below-par production processes at assembly plants [33]. The difficulties were ironed out by mid-summer when preparations began for another try.

The fifth Ye-1 class probe, still intended to accomplish lunar impact, was given the designation Ye-1A, to denote some minor modification to its instruments section which had been made as a result of the data received from the Cosmic Rocket spacecraft as well as the US Pioneer probe [34]. Launch was set for 16 June 1959 but an amusing incident thwarted that plan. During booster preparations, the director of the propellant-testing service had sent a young lieutenant to the fuel warehouse to check the quality of all the propellants. Later, when the propellants arrived at the launch site, it was discovered during a second test for quality that the density of the fuel in one of the tanks was too low. After further questioning, it was ascertained that the young lieutenant had tested only one tank and in the blazing summer heat of Kazkhstan had felt ill, and "hid from the heat in a dugout" [35]. By this time, the upper stage had already been fuelled with the incorrect propellant and the booster had to be destacked. The launch eventually went off successfully two days late on 18 June, but one of the gyro-instruments of the inertial guidance system of the upper stage failed at T+152 seconds and the booster was exploded by range control [36].

There was another failed launch attempt on 9 September although this time, launch operations were aborted on the pad when the core stage engine failed to reach the necessary thrust levels. A new 8K72 booster was wheeled out to the pad with the Ye-1A probe, the sixth in the series. Like the previous spacecraft of the same class, a special ball of pentagonal banners was installed on the main chassis to be left on the Moon as a reminder of the great significance of reaching the surface of another celestial body. On impact, each pentagonal segment with the USSR hammer-and-sickle insignia was to explode and scatter on the surface. This particular launch was also timed to fly according to Khrushchev's own plans. The Soviet leader was scheduled to visit the United States in September and had requested Korolev to time the launch of the lunar probe in time for his arrival. Korolev, in fact, had given Khrushchev two replicas of the ball of banners, one as a gift and the second to give to President Dwight D. Eisenhower [37].

The attempt on 12 September 1959 was the most successful yet. The booster lifted off as planned at 0939 hours 26 seconds Moscow Time and put the small probe on a trans-lunar trajectory. The 390.2 kilogram spacecraft, called the Second Cosmic Rocket in the Soviet press (and retroactively Luna-2), was only the second probe to achieve escape velocity successfully. The one kilogram of natrium was successfully released at a distance of 150,000 kilometres from the Earth and expanded to a cloud 650 kilometres in diameter which was visible from the ground. Ballistics experts had predicted that the impact time would be around midnight on 14 September. Korolev became more and more nervous as the slated time approached, not being able to sit still and often stepping outside the control centre to look at the night Moon.

He need not have worried: at exactly 0002 hours 24 seconds Moscow Time on 14 September, the probe's metronomic signal stopped, indicating that it had crashed onto the lunar surface.

It was the first object of human origin to make contact with another celestial body. The impact point was calculated to have been on the slope of the Autolycus crater, east of Mare Serenitatis [38]. The scientific data for the magnetometer had failed to detect a magnetic field 55 kilometres above the lunar surface and also found no sign of a lunar radiation belt. The day after the historic impact, Khrushchev triumphantly gave a replica of the ball of pendants to Eisenhower. It was a potent display of the power of politics in the emerging Soviet space programme.

5. THE FAR SIDE OF THE MOON

The next spacecraft in the lunar probe series was even more spectacular and utilised the first orientation system on a Soviet space vehicle. It was a foregone conclusion by the early 1950s that any spacecraft for photo-applications would have to have an active system of orientation for useful work. In a 1954 document on artificial satellites. Tikhonravov had repeatedly mentioned the need for such systems on the first satellites describing several potential variants for further development. The first serious research in this field was conducted at the NII-1, the Ministry of Aviation Industries' rocket engine research institute. In 1955, with institute DirectorAcademician Keldysh's authorisation, a 40 year old vibrations specialist named Boris V. Raushenbakh began a dedicated research project on the "controlled motion of space apparatus", with an initial focus on controlled orientation [39]. Raushenbakh, a man of many talents, had led a remarkably interesting life and was one of the few in the space programme who had known Korolev during his apprenticeship days at the NII-3 in the 1930s. He was also one of the many who had been sent off to the Gulag (in March 1942) having been arrested by the secret police as a result of his German heritage [40]. Incarcerated for a short time at a labour camp, he worked for a few years at Bolkhovitinov's famous design bureau before returned to Moscow in 1948 as a free man. It was then that he went to work for Keldysh at the NII-1 specialising in ramjet engines. He received his doctorate in 1958.

The orientation system project was coordinated in contact with Korolev's design bureau and, although not admitted as such, was clearly focused on military applications such as photo-reconnaissance. Raushenbakh's group finished their exploratory work in late 1956 but the opportunity to develop flight-worthy models of the orientation system did not emerge until Korolev needed one for his new lunar probes [41].

In their early conceptions of automated lunar probes, Korolev and Tikhonravov had projected a mission using the Ye-2 class spacecraft to photograph the far side of the Moon. Throughout 1958, the Department of Applied Mathematics of the V.A. Steklov Mathematics Institute (OPM MIAN), also headed by the ubiquitous Keldysh, had conducted serious mathematical investigations into the possible variations in mission profiles for exactly such a project. The requirements for the flight were numerous. The spacecraft had to be as close as possible to a straight line from the Sun to the Moon in order to have optimal lighting conditions; the probe had to be as close as possible to the Earth in order to transmit photographs to the Earth; and the spacecraft had to stay above the visible horizon over the Earth for as long as possible to ensure continuous retransmission of pictures. All these constraints also dictated the precise launch time of the spacecraft.

The Keldysh study, completed in January 1959, recommended two different missions profiles: one in October 1959 with the probe conducting photography after approach to the Moon and one in April 1960, with the spacecraft imaging the Moon prior to approach [43]. Korolev chose to take advantage of these two opportunities and Maksimov's group at the OKB-1 began the preparations of a series of Ye-2 spacecraft in the spring of 1959. Korolev contracted Raushenbakh's group at the NII-1 to design, develop and deliver a workable orientation system for the new probes in time for the first launch window.

The compact system developed by Raushenbakh's team was a tribute to simplicity and ingenuity [44]. The team was initially given a set of dimension and mass constraints by Maksimov's lunar probe team, and also a deadline by Korolev for completion of the task. Realising that the time available was very short, Raushenbakh opted to skip mathematical modelling and began by borrowing a thousand roubles from the institute and sending one of his young engineers to the local hobby store to buy a bunch of electronic components. Raushenbakh's group, a team of seven recent graduates from engineering schools, quickly developed a set of optical sensors, micro-thrusters with compressed gas, gyroscopes and electronic control devices from these children's parts [45]. The flight ready system, the first Soviet spacecraft orientation system, was then delivered to the OKB-1 for testing. Once the system was installed on the Ye-2 spacecraft, Korolev had given specific orders for it to be tested in near-realistic conditions. The flight model was suspended by ropes from a crane in the assembly building at Tyura-Tam and its on board batteries were switched on. Bright powerful searchlights were then turned on to simulate the light of the Sun. The spacecraft was to acquire the light source, fire its engines and orient itself properly to begin the photography regime. On this occasion, however, the probe simply continued to rotate lazily around its axis without any action. As onlookers watched in bemused silence, an order was passed on to bring the lights closer to the spacecraft. Still nothing happened. Eventually the search lights were turned off as the engineers pondered over the failure. At this point, one worker lit a match to light a cigarette and the spacecraft abruptly came to life, firing its attitude control thrusters in graceful motion. It was later ascertained that the spectral composition of the flood lamps was different from the Sun, thus having no effect on the spacecraft sensors [46].

Originally the farside variant of the lunar spacecraft was designed in two versions, the Ye-2 and the Ye-2A. They were distinguished only by their imaging and radio systems. The former's photo-television and radio system were designed and built by the Experimental Design Bureau of the Moscow Energetics Institute (OKB-MEI) headed by Chief Designer Aleksey F. Bogomolov [46a]. The imaging system had a single lens and optical scanning system. The device was designed based on the premise that the lunar probe would be equipped with an orientation system which would deposit the spacecraft in such a position that the optical axis of the imaging system would be in the view of the Moon within an angular dispersion of 30° [46b].

The photo-television system for the Ye-2A variant was built by the Scientific Research Institute No. 380 (NII-380) in Leningrad under the direction of Igor A. Rosselevich and Petr F. Bratslavets. After receiving their original contract in July 1958, the NII-380 designed and built their Yenisey-1 imaging system in the remarkably short time of just four months and delivered a working version to Korolev's engineers in October 1958 [22]. The system consisted of a 35 mm camera with two lenses of 200 (wide-angle) and 500 mm (high resolution) focal length, and a capacity to record up to 40 images. The process of filming would start only after receiving the command for precisely orienting the probe towards the Moon. The radio system for transmitting the images from the probe to Earth was designed and built by the NII-885 under Deputy Chief Designer

Boguslavskiy. For reasons that are not clear, the Ye-2 variant was passed over in favour of the Ye-2A version [46c].

The first Ye-2A spacecraft, launched successfully from Tyura-Tam on 4 October 1959, was perhaps the most remarkable and spectacular mission of the early space era. The 278.5 kilogram probe was inserted into a 48,280 x 468,300 kilometre orbit around the Earth, sufficient to sling it to a lunar distance around the far side of the Moon. The spacecraft itself had a different design from the earlier lunar probes. It was a 1.3 metre long cyndrical body covered by solar cells. These cells were direct modifications of the ones carried on Sputnik-3. Apart from the Yenisey-1 camera system, the spacecraft, called the Automatic Interplanetary Station in the Soviet press, also carried a micrometeoroid detector and a cosmic ray detector. As soon as the probe was on its correct trajectory, several serious problems were detected. Communications with the vehicle were intermittent at best and there was some concern that no photographs would be received. Furthermore, telemetry indicated a serious overheating malfunction which threatened to thwart the mission. The latter problem was fixed by carefully sending some commands to regulate the temperature. Eventually the probe passed over the Moon's southern polar regions at a distance of 7,900 kilometres before climbing up over the Earth-Moon plane.

At a distance of 65,200 kilometres from the lunar surface, ground control ordered gas jets at one end of the probe to stop the spin on the craft. A Sun sensor then locked on the Sun and the jets fired again so that a second sensor on the craft could locate the Moon. After alignment, the two lens systems were in view of the hidden surface. At 0630 hours Moscow Time on 7 October the cameras began taking the first of 29 exposures over a 40 minute period using "radiation-hardened" photographic film [48]. The exposed film was then developed, fixed and dried in an on-board automatic processor, following which a special light beam of up to 1,000 lines per image scanned the film for transmission to the Earth. There was a brief impatient attempt to try and receive the pictures from lunar distance but this proved unsuccessful. The ground controllers would have to wait until the probe was much closer to the Earth. By this time, a host of designers and specialists had assembled at the temporary control centre at Crimea to await the results of their work. As the expected time for retransmission approached on 8 October, the control centre was overpacked with people, raising the tension to unbearable levels. The first four attempts to receive the images were unsuccessful due to a low signal/noise ratio and Korolev and the rest of the designers almost began to lose hope [49]. The first two clear images were finally received on the fifth attempt when the probe was nearer to the Earth, as people crowded around to stare at the mysteries of the hidden side of the Moon. Of the total of 29 images received, 17 were deemed of 'satisfactory' quality, allowing Soviet astronomers to name the Mare Moskovraye and Mare Desiderii as well as the Tsiolkovskiy crater. Approximately 70 percent of the lunar farside was photographed, showing far fewer mare areas, which prompted revisions of existing theories on lunar evolution. Contact with the Ye-2A probe was eventually lost in November and the spacecraft re-entered the Earth's atmosphere on 20 April 1960.

There was a fitting epilogue to the mission of the Automatic Interplanetary Station. A French winemaker had engaged in a bet offering a thousand bottles of his finest wine from his cellar for whoever managed to first take a look at the hidden side of the Moon. After the mission in October, the wine-maker had apparently kept his promise, delivering the bottles to the Academy of Sciences in Moscow. These were eventually delivered to the OKB-1 and, over the years, Korolev would often take out a bottle or two to give to his favourite employees [50].

6. THE FINAL LAUNCHES

The series of far-side photography spacecraft were closed by two launch attempts in April of 1960 when the goal was to image the far side during approach instead of after the flyby. The spacecraft, the Ye-2F, were distinguished by the presence of a slightly modified photo-television system designated the Yenisey-2, which was developed by the NII-380 like its predecessor [50a]. Before launch, the Ye-2F was confusingly given the now defunct Ye-3 designation, which had originally represented the bomb-on-the-Moon project [51].

The first Ye-3 probe was launched as scheduled at 1806 hours 42 seconds Moscow Time on 15 April 1960; unfortunately the upper stage with the RD-0105 engine cut off prematurely and the probe received insufficient velocity to reach escape velocity. It reached an altitude of 200,000 kilometres and then fell back in to the Earth's atmosphere much like the US Pioneer-1 and Pioneer-3 probes [52]. There may have been political pressure to have a space success. There are unconfirmed reports that Khrushchev may have wanted to celebrate his birthday with a spectacular space mission.

Another Ye-3 probe was wheeled out for launch on the afternoon of 19 April. This time there was indeed a spectacular, but not one which Khrushchev had perhaps desired. After lift-off, an engine in one of the four strapon boosters of the 8K72 launch vehicle failed to achieve full thrust. Although the vehicle took off, the strapon abruptly broke away at T+0.4 seconds and the entire booster began to fall apart. All of the strapons separated from the core and huge explosions followed one after another. Two of the strapons fell near the launch pad, the third landed one-and-a-half kilometres away nearly killing a number of technicians, while the fourth impacted near a railway bed that passed under the windows of the Assembly Test Building. The building was severely damaged by the explosion, while the launch pad, although intact, was strewn with broken glass. The core stage of the launcher itself flew about one kilometre away to land and explode in a salt lake [53].

This truly spectacular failure ended the first generation series of launches in the Soviet lunar probe programme. Out of nine launch attempts in the Ye-1, Ye-1A, Ye-2A and Ye-3 series, there had been six outright failures, one partial success and only two complete successes. Despite the poor record which, in fact, compared favourably with US attempts at the time, the achievements of the programme had been dramatic. Apart from the purely technical accomplishments of introducing a new launch vehicle and a spacecraft orientation system, the OKB-1 had successfully claimed three important firsts for the Soviet space programme.

It was a stunning display of technical expertise that put the Soviet Union far ahead of its principle rival in the first lap of the so-called 'space race'.

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2. An abridged version of Korolev's speech has been published in S.P. Korolev, "Investigations of the Upper Layers of the Atmosphere with the Aid of Long-Range Missiles" (in Russian) in M.V. Keldysh, Ed., *Tvorcheskoye naslediye Akademika Sergeya Pavlovicha Koroleva: izbrannyye trudy i dokumenty*,

Moscow: Nauka, 1980, pp.348-361.

3. A.Yu. Ishlinskiy, Ed., *Akademik S.P. Korolev: Ucheniy, inzhener, chelovek*, Moscow, Nauka, 1986, p.447; B.V. Raushenbakh, Ed., *Materialy po istorii kosmicheskogo korablya "Vostok"*, Moscow, Nauka, 1991, p.210.
4. Timothy Varfolomeyev, "Soviet Rocketry that Conquered Space: Part 2: Space Rocket for Lunar Probes", ***Spaceflight*, 38**, February 1996, pp.49-52.
5. Yaroslav Golovanov, *Korolev: fakty i mify, Moscow*, Nauka, 1994, p.589; Christian Lardier, *L'Astronautique Sovietique*, Paris, Armand Colin, 1992, p.120. The other two sections were headed by K.P. Feoktistov (piloted space vehicles) and V.N. Dudnikov (communications satellites).
6. Golovanov, 1994, p.557.
7. The complete text of this letter has been published as M.V. Keldysh and S.P. Korolev, "On the Launches of Rockets to the Moon" (in Russian) in V.S. Avduyevskiy and T.M. Eneyev, Eds., *M.V. Keldysh: izbrannyye trudi: raketnaya tekhnika i kosmonavtika*, Moscow, Nauka, 1988, pp.241-242; Golovanov, 1994, pp.557-558.
8. 'Ye' is the sixth letter in the Russian Cyrillic alphabet, preceded by 'A', 'B', 'V', 'G' and 'D', all of which were used to denote payloads for the R-7. The Object D was the earliest satellite project. The date for approval is given in Yu. P. Semenov, Ed., *Raketno-Kosmicheskaya Korporatsiya "Energiya" imeni S.P. Koroleva*, Korolev: RKK Energiya named after S.P. Korolev, 1996, p.93.
9. The complete report on the four variants of the Object Ye is reproduced (with disguised designations) in S.P. Korolev, "On A Programme of Lunar Exploration" (in Russian) in *Keldysh*, 1980, pp.400-404. A seven-point program of scientific study was also announced. This comprised: the detection and study of the lunar magnetic field; the study of cosmic rays outside the Earth's magnetic field at a distance of 400,000 to 500,000 kilometres; the detection and study of radioactive lunar radiation; the study of gas components in space matter; the study of micro-meteorites flows in space; the study of electrostatic fields in space; and the taking of pictures of the farside of the Moon. The variant designations are from B.Ye. Chertok, *Rakety i lyudi: Fili Podlipki Tyuratam, Moscow; Mashinostroyeniye*, 1996, pp.240-241.
10. Varfolomeyev, 1996. Note that the designations in the listed source are slightly different.
11. The go-ahead for US lunar probes was given on 27 March 1958, the very same month that the Soviet government approved Korolev and Keldysh's proposals. See Linda Neuman Ezell, *NASA Historical Data Book: Volume II: Programs and Projects 1958-19968*, Washington, DC: NASA SP-4012, 1988, 303; Andrew Wilson, *The Eagle Has Wings: The Story of American Space Exploration 1945-1975*, London: The British Interplanetary Society, 1982, p.18.
12. Keldysh, 1980, 27. A test version of this comet was launched on an R-5A suborbital scientific missile on 19 September 1958 from Kapustin Yar to an altitude of 430 kilometres. See Semenov, 1996, p.54.
13. Golovanov, 1994, 5589; K. Lantratov, "25 Years for Lunokhod-1: I" (in Russian), *Novosti kosmonavtiki* (November 5-18, 1995) No. 23, pp.79-83; Chertok, 1996, pp.241-242.
14. Missing
15. Vasiliy P. Mishin, "...He Said, "Here We Go!" (in Russian) *Aviatsiya i kosmonavtika*, April 1991, No. 4, pp.13-14; Varfolomeyev, 1996.
16. Igor Afanasyev, "Absolutely Secret: N-1: I" (in Russian) *Krylya rodiny* (September 1993) No. 9, pp.113-16; T. Varfolomeyev, "Readers' Letters: On Rocket Engines from the KB of S.A. Kosberg, and Carrier on Which They Were Installed" (in Russian) *Novosti kosmonavtiki* (December 18-31, 1993), No. 4, pp.79-80. The other three engines developed by Glushko using UDMH were the RD-216, the RD-218 and the RD-219. The RD-109 itself was also known as the 8D79.
17. This particular engine was the SK-1K.
18. Golovanov, 1994, pp.559-560; Yu.V. Biryukov, "Materials for the Biographical Chronicles of Sergey Pavlovich Korolev" (in Russian), in B.V. Raushenbakh, Ed., *Iz istorii sovetskoy kosmonavtiki*, Moscow, Nauka, 1983, p.240; V.N. Ivanenko, "On the Life and Activities of S.A. Kosberg (On His 80th Birthday)" (in Russian), *Iz istorii aviatsii i kosmonavtiki* (1984) **Vol. 49**, pp.3-10. The RD-0105 engine was also known as the 8D714.
19. B.A. Pokrovskiy, *"Zarya" - Pozyvnoy Zemli*, Moscow, Moskovskiy rabochiy, 1987, p.177; I. Meshcheryakov, "Ensuring Space Flights: The Center for Long-Range Space Communications" (in Russian) *Aviatsiya i kosmonavtika*, (June 1988), No. 6: pp.42-43.
20. Col. M. Rebrov, "The Whiteness of Martian Seas...: Pages of the Life of the Chief Designer of Space Radio Control Systems" (in Russian) *Krasnaya zvezda* (March 11, 1989) p.4.
21. B. Pokrovskiy, "Space and Radio" (in Russian) *Aviatsiya i kosmonavtika*, (May 1987), No. 5: pp.44-45; Pokrovskiy, *"Zarya" - Pozyvnoy Zemli*, 1987, pp.180-181. The three heads of the centre were: Ye.Ya. Boguslavskiy, G.A. Sytsko and N.I. Bugayev.
22. T. Varfolomeyev, "Readers' letters: The Unknown Ye Series" (in Russian) *Novosti kosmonavtiki* (January 15-28, 1996) No. 2, pp.43-44.
23. Semenov, 1996, 95: Timothy Varfolomeyev, "Soviet Rocketry that Conquered Space: Part 3: Lunar Launchings for Impact and Photography", ***Spaceflight*, 38**, June 1996, pp.206-208; A. Poluektov, "A 'Hunt' for the Moon" (in Russian) *Selskaya zhizn* (April 5, 1991), p.4. Note that there had also been a prior suborbital test of the 8K72 booster without the new upper stage (named the 8K71/III) on 19 July 1958 which had failed shortly after lift off.
24. Poluektov, 1991.
25. Varfolomeyev, "Soviet Rocketry that Conquered Space: Part 3: Lunar Launchings for Impact and Photography", 1996.
26. Yu. A. Mozzhorin et al., Eds., *Nachalo kosmicheskoy ery: vospominaniya veteranov raketno-kosmicheskoy tekhniki i kosmonavtiki: vypusk vtoroy* (Moscow: RNITsKD, 1994), p.174: Varfolomeyev, "Soviet Rocketry that Conquered Space: Part 3: Lunar Launchings for Impact and Photography", 1996; Ishlinskiy, p.256; Golovanov, 1994, pp.560-561.
27. Poluektov, 1991; Varfolomeyev, "Soviet Rocketry that Conquered Space: Part 3: Lunar Launchings for Impact and Photography", 1996.
28. Ezell, 1988, p.306.
29. Golovanov, 1994, pp.566-567.
30. Mishin and Raushenbakh, 1986, p.123.
31. Lardier, 1992, p.115.
32. Golovanov, 1994, p.567.
33. Golovanov, 1994, p.569.
34. Lantratov, 1995.
35. Poluektov, 1991.
36. Varfolomeyev, "Soviet Rocketry that Conquered Space: Part 3: Lunar Launchings for Impact and Photography", 1996; Poluektov, 1991; Semenov, 1996, p.96.
37. Golovanov, 1994, p.566. The inscription read "USSR, September 1959". See also Sergey Khrushchev, *Nikita Khrushchev: krizisy i rakety: vzglyad iznutri: tom 1*, Moscow, Novosti, 1994, p.473.
38. The coordinates were said to be 30° north latitude and 0° longitude.
39. V.P. Leogstayev, "18 January - 75 Years From the Birth of Soviet Scholar and Designer B.V. Raushenbakh (1915)" (in Russian) *Iz istorii aviatsii i kosmonavtiki* (1990) **Vol. 64**, pp.4-7.
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42. Missing
43. The complete text of the OPM MIAN report on lunar trajectories is reproduced in M.V. Keldysh, Z.P. Vlasova, M.L. Lidov, D.Ye. Okhotsimskiy and A.K. Platonov, "Research on Circular Luna Trajectories and Analyses of Various Photographing and Transfers in Information" (in Russian) in Avduyevskiy and Eneyev, 1988, pp.261-309. The exact projected launch windows were 4-6 October 1959 and 15-17 April 1960.
44. The complete report on the active orientation system for the Ye-2 class of lunar probes is reproduced in M.V. Keldysh, Ye. A. Bashkin, D.A. Knyazev, V.P. Legostayev, V.A. Nikolayev, A.I. Patsiora, B.V. Raushenbakh and B.P. Skotnikov, "Technical Plan for the System of Orientation of the Object 'Luna-3'" (in Russian), in Avduyevskiy and Eneyev, 1988, pp.310-335. The study was completed in May 1959.
45. Golovanov, 1994, pp.574-575.
46. Kashits, 1991.

46a. Semenov, 1996, p.97.

46b. Varfolomeyev, "Readers' Letters: The Unknown Ye Series", 1996.

46c. Semenov, 1996, p.97. Note that in the same source, it is stated that the SKB-567 led by Chief Designer Yevgeniy S. Gubenko designed the photo-television apparatus. Possibly this was a cooperative venture between the NII-380 and the SKB-567. One source says that the Ye-2A's radio-station was placed on the bottom end of the spherical probe unlike the Ye-2 version. See Lantratov, 1996.

47. Lardier, 1992, 115. Rosselevich was the Director of the NII-380.
48. Ishlinskiy, 1986, pp.351-355; Boris V. Rauschenbach, "The First Control System for Space Vehicles", in John Becklake, Ed., *History of Rocketry and Astronautics*, **Vol. 17** (San Diego, CA: American Astronautical Society, 1993) pp.197-201; Andrew Wilson, *Solar System Log*, London, Jane's publishing Company Limited, 1987, pp.19-20.
49. Kashits, 1991.
50. Ivan Borisenko and Alexander Romanov, *Where All Roads into Space Begin*, Moscow: Progress Publishers, 1982, pp.38-39.

50a. Varfolomeyev, "Readers' Letters: The Unknown Ye Series", 1996. The Yenisey-2 also had two lenses like the Yenisey-1.

51. Chertok, 1996, p.310.
52. Kashits, 1991; Varfolomeyev, "Soviet Rocketry that Conquered Space; Part 3: Lunar Launchings for Impact and Photography", 1996.
53. Poluektov, 1991; Kashits, 1991; Varfolomeyev, "Soviet Rocketry that Conquered Space: Part 3: Lunar Launchings for Impact and Photography", 1996.

* * *

CORRESPONDENCE

Dear Sir,

Soviet Co-orbital Anti-Satellite System

Mr. Siddiqi should be congratulated on his survey of recent Russian literature pertaining to the former Soviet co-orbital ASAT programme (*JBIS*, **Vol. 50**, pp. 225-240). His synopsis is indeed a valuable contribution to Western understanding of this important military space system. I have had the pleasure of discussing the Soviet ASAT with Designer General Savin in Moscow in 1992 and later examined the Polet spacecraft at Chelomel's design bureau, subsequently known as Machinostroenye NPO.

Unfortunately, in his description of this individual space tests, with few Russian references to guide him. Mr. Siddiqi has included a number of misconceptions and errors. First, Russian specialists have now acknowledged that at least 17 of the 20 interceptors discharged their pellet warheads during the tests [1], and the remaining three vehicles may have followed suit. Eight of these firings occurred after the interceptor had entered a de-orbiting trajectory, and, hence, no debris was left on orbit. The de-orbital technique was unrelated to the success of the test.

Secondly, the time and location of the warhead firings of the nine tests which resulted in *orbital* debris have been in the open literature for more than 12 years [2]. This information clearly denotes the difference between a potentially successful mission (discharge of the warhead in the vicinity of the target) and a failed one. Actually, such information has always been available by a simple examination of the orbital parameters of the debris as determined by the US Space Surveillance Network and distributed to the public by the NASA Goddard Space Flight Center. The <1 km criterion cited in Mr Siddiqi's article was a necessary but not a sufficient condition to assess the test successful. Note that a target satellite was never used again after a successful engagement for obvious reasons.

In addition, the intercepts against Kosmos 373 did not take place 600 km lower than those against Kosmos 248, as stated by Mr Siddiqi. All four intercepts occurred between 525 and 535 km (as noted in my work, *Soviet Military Strategy in Space* [1971], cited by Mr Siddiqi), although the rendezvous orbits of Kosmos 374 and Kosmos 375 had apogees 600 km below those of Kosmos 249 and Kosmos 252. The rendezvous orbit of each interceptor was governed by the phasing of the target satellite at the time of the ASAT launch. A final manoeuvre was conducted shortly before intercept to establish specific engagement conditions. The orbital behaviour of Kosmos 404 satisfied these conditions and was not indicative of an inspection mission or a failed intercept. Some of Mr Siddiqi's descriptions of other intercepts are also in error.

N.L. Johnson
Texas, USA

References

1. "History of Soviet/Russian Satellite Fragmentations -A Joint US-Russian Investigation", N.L. Johnson, G.M. Chemyavskiy and N.P. Morozov, prepared by Kaman Sciences Corporation for NASA Johnson Space Center, October 1995. A synopsis of this work was presented at the 1st International Workshop on Space Debris in Moscow, October, 1995.
2. "History of On-Orbit Satellite Fragmentations", First Edition, G.T. DeVere, J.. Gabbard, E.E. Johnson and N.L. Johnson, prepared by Teledyne Brown Engineering for NASA Johnson Space Center, August, 1984. (Nine further editions were published through 1996).

Reply to letter from Nicholas Johnson:

I thank Mr Johnson for his insightful comments on my article. The reference 1 to which he refers to was unknown to me and his details on the number of interceptors which discharged their pellets is an invaluable contribution to understanding the history of the ASAT project.

As mentioned in the original article, my intention was to explore the actual interceptions only in a cursory manner, i.e. the main thematic goal of the article was to illuminate the institutional and technical background to the ASAT program. Thus, the analyses of the orbital interceptions was taken not from primary sources, but rather from two secondary sources: Nicholas Johnson's *Soviet Military Strategy in Space*, and Paul Stares' *The Militarization of Space: US Policy, 1945-1984*.

As far as Mr Johnson's specific points are concerned

(1) He is correct in pointing out that the interception of Kosmos-373 did not take place 600 kilometres lower than those against Kosmos-248. This was my mistake.

(2) He writes that Kosmos-404's behaviour was not indicative of an inspection mission or a failed intercept. My claim in the article was merely that "it has been *suggested by Western analysts* that the Kosmos-404 mission may have had an inspection rather than an interception goal," not that it was actually so.

Again, I would like to thank Mr Johnson for his valuable comments. Since he is one of the most expert analysts in the field, one hopes that he would find time to update his original analyses from the 1980s on the Soviet ASAT program. Such a study would be a significant asset to the understanding of the project.

In finishing I would like to add some more information to the article which was unavailable at the time of my submission of the original text.

(I) DESIGNATIONS

Mr Sergey Voevodin reports in VSA072 that the ASAT project had a variety of different models:

For the early tests (up to 1971):

Design	Index	Name	1st Flt	Description
I-1P	-	-	-	anti-satellite test
I-2P	-	-	-	anti-satellite interceptor
I-2M	-	-	-	anti-satellite target

Here, I-1P appears to have been the Polet mission(s). I-2P and I-2M were evidently the interceptor ['Perekhvatchik'] and target ['Mishen'] respectively, both flown prior to 1971. There may have been a modification of the I-2M designated the I-2BM.

Additionally, for the later tests:

Design	Index	Name	1st Flt	Description
IS-A	4Ya11	-	-	anti-satellite interceptor
IS-P	5V91T	Uran	-	anti-satellite target
IS-MU	14F10	Naryad	-	anti-satellite ?

It is not clear yet which particular satellites the above designations represent. I had already mentioned in the original article that the IS-MU was declared operational in 1991, evidently without flying in space.

Finally, a recent article by Vladimir Agapov entitled "Marking the Anniversary of the First DS Launch" (in Russian) in *Novosti Kosmonavtiki* (March 10-23, 1997), 54-64, has revealed new information on both targets and support systems. An entire class of small satellites designated DS-P1 were developed for PRO (anti-missile defence), PKO (anti-space defence), PRO (air-aircraft defence), and SKKP (system for monitoring outer space) purposes. The 'DS' stood for 'Dnepropetrovsk Satellite.' The makers of these satellites, Chief Designer M. K. Yangel's OKB-586, was located at Dnepropetrovsk in Ukraine.

The following classes of DS-P1 satellites were launched:

Design	Index	Name	1st Flt	Description
DS-P1	-	-	Kosmos-6	PRO/PKO radar calibration
DS-P1-Yu	11F618	-	Kosmos-36	PRO/PKO radar calibration
DS-P1-I	11F620	-	Kosmos-106	PVO/SKKP radar calibration
DS-P1-M	11F631	Tyulpan	Kosmos-394	PKO target

The DS-P1 appears to be have been an initial test version, four of which were launched between June 1962 and February 1964. Of these, one failed to reach orbit.

The first mission-specific DS-P1 was the DS-P1-Yu, which I mentioned in the original article. Of the 79 satellites in this class which were launched between July 1964 and August 1976, seven failed to reach orbit.

Of the DS-P1-I, 19 were launched between January 1966 and June 1977, of which one failed to reach orbit.

It is possible that the Vektor, Yug, and Romb satellites which I mentioned in the original article, replaced the DS-P1-Yu and DS-P1-I satellites.

Finally, the DS-P1-M were ASAT targets used in the 1971-72 period. The list of DS-P1-M launches are taken from Mr Agapov's article. The index (11F631) is from Mr Voevodin.

Kosmos	Index	S/C	Launch Date Site	Booster
-	11F631	DS-P1-M n1	0030 Dec 23 1970 P-132/2	11K65M
394	11F631	DS-P1-M n2	2149 Feb 9 1971 P-132/1	11K65M
400	11F631	DS-P1-M n3	0045 Mar 19 1971 P-132/1	11K65M
459	11F631	DS-P1-M n5	2030 Nov 29 1971 P-132/1	11K65M
521	11F631	DS-P1-M n4	2319 Sep 29 1972 P-132/2	11K65M

(II) ORGANISATIONS:

Obviously based on the above information, it possible to say that the OKB-586 was responsible for the design and creation of one set of the ASAT targets.

Additionally, an article by Anatoliy Dokuchayev entitled "The Russians Did Not Shoot Down American Satellites, However Our Country was Ready to Win the Skirmish in 'Star Wars' "(in Russian) in *Krasnaya zvezda* (July 30, 1994), p. 2, has added some new elements to the background of the Kometa organisation, the prime contractor for the development of the ASATs. As I speculated in the original article, the TsNII Kometa was indeed a part of the larger KB-1 organisation in the 1960s, separating from the KB-1 in later years. Additionally, it was revealed that the Machine Building Plant Named After S. A. Lavochkin was responsible for the manufacture of the ASAT interceptors.

According to the author of the article, speaking of ASAT testing, he writes that "It goes without saying that there were failures. However, on the whole, the hit rate was almost one hundred percent." Later he explicitly states that by 1983, at least 10 satellites had been destroyed in space. Confirming what I hypothesised in the article, the author states that after 1983, "The further development of the [ASAT] complex proceeded on the ground, based on previously accumulated data."

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