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Front Cover: **The External Tank of shuttle mission STS-78 is jettisoned on 20 June 1996 against a backdrop of the Indian Ocean. The mission was less than 10 minutes old when a crew member recorded this 35 mm image. The burn scar from the separation motors is clearly visible. NASA is introducing a super light-weight External Tank in order to increase shuttle cargo carrying capacity to the International Space Station, see pp.374-376.** NASA

Before Sputnik: Early Satellite Studies in The Soviet Union 1947-1957 - Part 2

The launch of the first Sputnik was the outcome of a long history of research on artificial satellites that was carried out in the Soviet Union as an adjunct to military reconnaissance. In Part 1, we saw that progress suffered setbacks due to personal differences and the predominance of military interests. The fact that it continued at all owes much to the vision of two people, Sergey Korolev and Mikhail Tikhonravov. These two people followed different careers within the Soviet system, Korolev being a long-serving Chief Designer at the Scientific Research Institute No. 88 (NII-88), while Tikhonravov suffered eventual demotion on account of his "space dreams" and found himself for some time in a backwater. Nevertheless, they pulled together making their own individual contributions to keep the vision alive. The events that enabled the vision to become reality are now the subject of the concluding Part 2 of this article.

BY ASIF A. SIDDIQI
Philadelphia, USA

Gaining 'Official' Status

The relationship between Korolev's NII-88 and the NII-4 (Scientific Research Institute No. 4) is said to have dramatically improved in the two years following April 1953 when the Academy of Artillery Sciences was finally dissolved after a tumultuous existence and the NII-4 was brought directly under the control of the USSR Ministry of Defence.

These years culminated in the appointment of a Maj.-Gen. Andrey I. Sokolov, another *Katyusha* veteran as the new NII-4 Director [1]. Sokolov apparently had a much more favourable attitude towards Tikhonravov's work and an employee of the institute later recalled that "in connection with Sokolov's [appointment] there was a sharp reinforcement of work on space themes" [2]. Furthermore, the number of people in Tikhonravov's satellite and launch vehicle group is also said to have increased dramatically following the change in the NII-4 leadership.

The most important work under Tikhonravov had already taken place prior to Sokolov's appointment as Director. Following the 'purges' at the NII-4 in the early 1950s, Tikhonravov cooperated with a number of his former protégés to conduct "unofficial" research into the topic of artificial satellites, producing three important memoranda in 1952-53 and early 1954 which answered four of the most important questions required for the creation of a satellite. These were:

- What kind of satellites could by launched by the early version of Korolev's new R-7 intercontinental ballistic missile;
- What kind of equipment could be placed in them;
- How were they to be controlled with special orientation systems; and
- What problems could they solve that had both scientific and military goals. [3]

At the prompting of Korolev, Tikhonravov himself appears to have played an important role in moving his work to 'official' status. Armed with two large sketchbooks, he made an appointment to meet Georgiy N. Pashkov, the Deputy Chairman of the special commission in the Council of Ministers responsible for all defence industrial issues. In one of the books were a huge number of clippings from the Western press with descriptions of American 'plans' for artificial satellites. The other sketchbook contained detailed drawings and calculations proving that not only was such a launch within the grasp of Soviet technology, but that if given approval, any Soviet satellite would be ten times heavier than any US satellite [4].

Pashkov was sufficiently impressed by Tikhonravov's presentation to telephone Marshall Aleksandr M. Vasiliyevskiy, the former Minister of Defence who was at the time a Deputy in the ministry, to permit some modest but official support for Tikhonravov's work. Subsequently, a two-year dedicated scientific research programme on the creation of an artificial satellite was approved on 16 September 1953, the first official and dedicated effort in the USSR on such a topic [5].

Tikhonravov's group, composed of most of the same individuals who had participated in his earlier ICBM studies including Bazhinov, Maksimov, Soldatova and Yatsunskiy, once again coordinated their work closely with Korolev, although the two did not have any formal institutional connections [6].

Korolev also consulted with Academician Mstislav V. Keldysh to undertake parallel studies at his Department of Applied Mathematics of the V.A. Steklov Mathematics Institute of the Academy of Sciences (OPM MIAN). With an affiliation to the Academy this effort was perhaps easier to justify, and the same young individuals at the OPM MIAN who had provided much of the brain power for the design of the first Soviet ICBM began a new effort to solve the problems involved in the "ballistic return of a space apparatus from Earth orbit and to show the possibility of using this method of recovery of piloted flights" [7]. Despite the fact that these studies did not envision actual launches, it was a giant step forward for Korolev and Tikhonravov, for it proved that the climate for space research was opening up.

In January 1954 Korolev began to consolidate all the current work on space issues. This was perhaps prompted by the deadline of May 1954 for submissions to participate in the International Geophysical Year (IGY), a cooperative international programme for the study of the Earth and its upper atmosphere from high altitudes [8]. His strategy was to finalise a request document, obtain the formal support of the USSR Academy of Sciences, and then finally ask for approval from the government in the form of a decree.

In beginning his lobbying efforts, Korolev spoke with Keldysh on 23 January to schedule a meeting between the scientists at the NII-4 and the OPM MIAN in order to coordinate the entire effort [9]. The Chief Designer also personally telephoned his governmental boss, Minister of Defence Industries Ustinov on 7 February as a preliminary move, informing him that Tikhonravov's group had prepared a document on artificial satellites which he would be sending to the government for approval. Ustinov was restrained but added that he would review the document when it was on his desk [10].

The 1954 Proposal

Tikhonravov had by this time prepared a detailed report on satellites based on his three memoranda from

1952-54 with the primary help of aides Yatsunskiy and Maksimov. The basic version of the document was then modified based on comments from Korolev, his Deputies Mishin and Bushuyev and Chief Designer Glushko. A meeting to discuss further changes was held on 16 March at which for the first time the scientists from the OPM MIAN and the NII-4 met each other. Present apart from Keldysh, Korolev, and Tikhonravov was Academician Petr L. Kapitsa, the famous Soviet nuclear physicist [11]. A draft version of the report was then typed up at the end of March before Keldysh took the matter to the President of the Academy of Sciences Aleksandr N. Nesmeyanov at a meeting on 24 April.

Nesmeyanov was supportive of the general topic and promised to support its adoption by the Academy. Final revisions of the typed document were carried out on 13 May during a session with Korolev, Tikhonravov, and two of 'Keldysh's boys' Timur M. Eneyev and Vsevolod A. Yegorov. Support from the Academy was then finalised 12 days later during a formal meeting of the Presidium of the Academy in the presence of Korolev, Tikhonravov, Keldysh, and Nesmeyanov among others. The three hour long session ended with a fully approved plan. As Tikhonravov wrote later in his personal journal: "All has been signed...one may say that the first stage is finished." [12]

The next step was securing the support of the military. Korolev approached NII-4 Deputy Director Maj.-Gen. Georgiy A. Tyulin, an old friend from the Germany days. The latter was not, however, particularly enthusiastic, and Korolev only agitated Tyulin more when he began to overtly pressure him to give his consent. Tikhonravov was disappointed, but had already secured the support of Marshall Vasiliyevskiy who, having read the report, wrote back with gusto: "Comrade Tikhonravov: If you have any problems, call me at any moment..." [13].

Despite the rebuke from Tyulin, Korolev prepared three copies of Tikhonravov's report, each attached with a cover letter authored by himself and a set of translations of articles on satellites published in the West. He sent a set of each, the day after the Academy of Sciences meeting on 26 May 1954, to Ryabikov, the Chief of the Glav Spets Montazh, which was temporarily overseeing the missile programme, Ustinov, and Pashkov [14]. It had been just six days since the R-7 ICBM project had been formally approved by the government, and Korolev was already asking permission to launch a satellite with it.

Tikhonravov's document, remarkable even in the present day, was a tour de force of foresight in the mid-1950s. Classified top secret for 37 years, it was finally published in its original form in 1991, just prior to the dissolution of the Soviet Union [15]. The report, entitled "Report on an Artificial Satellite of the Earth," began:

> At the present time there is the real technological possibility to achieve sufficient velocity with the use of a powerful rocket for the creation of an artificial satellite of the Earth. Most realistic and feasible in the shortest time is the creation of an artificial Earth satellite composed of automatic instruments which will have scientific apparatus on the exterior, carry out radio communications with the Earth and circle the Earth at a distance on the order of 170-1,110 kilometres from the surface. Such a capsule will be the simplest satellite. [16]

The complete report was divided into two broad thematic sections: the first focused on immediate objectives of a space programme, and the second focused on long-term goals. The immediate goals were to:

- Create and launch the simplest satellite into Earth orbit;
- Launch a human on a 'vertical' trajectory into space; and
- Recover a portion of the simplest satellite from Earth orbit.

These three goals were to be carried out in parallel with each other and with the development of the R-7 ICBM which would facilitate the first objective. Throughout the document, Tikhonravov goes into unusual detail for a report aimed at government bureaucrats, and one wonders, given the times, how much of it Ustinov or the others truly comprehended. The description of the simple satellite includes explanations of its launch trajectory, characteristics of various potential orbits, its albedo in the night sky, three different orientation systems, power sources, and on-board instrumentation. Interestingly, he mentions a 'special cassette' with scientific data which would be recovered; this presumably would be exposed film of the Earth's surface. Furthermore, a 300 kg television system would also be installed on the satellite for transmitting images of the Earth. Acknowledging that the creation of an oriented satellite would be a complex task, Tikhonravov wrote that "in the event of the impossibility of a speedy solution [to installing an orientation system], it would be agreeable to having an unoriented [satellite], since besides scientific importance, the launch of the first satellite in our country would also have vast political significance" [17]. The total mass of the vehicle was noted at 3,000 kg, composed of orientation systems, power sources, communications systems, a TV unit, a recoverable cassette, film, scientific apparatus, and a container for an animal to be installed on later simple satellites.

The second section of the report dealt with the launch of humans on vertical flights into space. Although particular rockets were not mentioned, it is likely that the reference was not to the R-7, but rather more modest missiles such as the R-2 and R-5 in their scientific versions. It was also noted that these vertical launches would progress to true suborbital missions downrange. Experience from the aviation industry was to be used to design and construct appropriate cockpits for the single passenger. The third section addresses the methods of returning either the complete satellite or a portion of it to the Earth. Both ballistic return or re-entry with the aid of wings are detailed.

The final section deals with future work:

- The creation of an "experimental satellite with humans";
- The creation of a "satellite-station"; and
- The "problems of reaching the Moon." [18]

It is clear from the repeated mentions in the entire document that Tikhonravov and Korolev's primary goal is to put one to two humans into Earth orbit on board a satellite. In fact, at one point, the simplest satellite is described as "an apparatus without people." Orbital human space flight, according to the writing in the document would be possible to solve in the nearest future based on results of the three preliminary goals. The so-called "satellite-station" was merely an extension of piloted space flight, and orbital assembly is mentioned as a means of creating a large space station in Earth orbit crewed by specialists.

The final long-term goal is the first ever official note in a Soviet document of plans to send spacecraft to the Moon. Although piloted flight is not explicitly mentioned, Tikhonravov describes a 1.5 ton spacecraft capable of landing on the Moon and then returning to the Earth by means of atmospheric braking. A three-stage 'packet' type rocket, i.e. a hypothetical launch vehicle with a lifting mass of about 650 tons, would be used for this purpose, although it is acknowledged that engine performance would have to be increased significantly for such a mission. There is even mention of interplanetary flight which would be possible after accomplishment of the lunar expedition.

In the conclusion, Tikhonravov lists a number of goals of the complete programme, focusing mostly on the scientific aspects, but notes that the creation of an artificial satellite would be of great importance to "defence." Korolev's attached letter was short and to the point:

> I draw your attention to the report of Comrade M. K. Tikhonravov, "Report on the Launch of Artificial Satellites of the Earth," and also to the forwarded materials of the work on this sphere being carried out in the USA. The

current development of a new article [the 8K71 R-7] makes it possible for us to speak of the possibility of developing in the near future an artificial satellite. By reducing the mass of the payload somewhat, we will be able to achieve the final velocity of 8,000 m/s necessary for a satellite. The article - the satellite may be developed on the basis of the new article [the R-7] being developed now, referred to above, however with major modifications to the latter. It seems to me that in the present time there is the opportunity and expediency of organising a scientific-research department at the NII-88 for carrying out the initial exploratory work on a satellite and more detailed work on complex problems involved with this goal. We await your decision. [19]

This document was the blueprint for the early days of the Soviet space programme and stands testament to the vision of both Korolev and Tikhonravov. Most of the goals were eventually accomplished although in 1954 none of the participants involved could foresee the eventual impact of the report. In fact, the immediate result of Korolev's communication with Ustinov, Ryabikov, and Pashkov was not encouraging. His letters appear to have disappeared in a sea of red tape. It took over a year for a concrete decision from the government.

Sputnik, Vostok and Zenit

Incredibly, for almost a year, the satellite issue was essentially dead in the water, and although Korolev continued to lobby for this proposal, he appears to have been diverted to more important matters relating to the operation of the nuclear-tipped R-5M missile and of course, the work on the R-7 ICBM. But the impact of the 1954 was long-lasting.

By 16 July 1955, Tikhonravov had completed his two year study on artificial satellites and sent Korolev the completed report, essentially based on the May 1954 document, suggesting a reduced mass in the range of 1,000 to 1,400 kg for the satellite [20]. This report was eventually used as the basis for official approval by the Academy of Sciences and the Military-Industrial Commission for a dedicated Soviet artificial satellite project on 30 August 1955 [21]. At a formal meeting on that date, Korolev reported that the Council of Chief Designers at a recent session had conducted a detailed examination on modifying the original R-7 into a vehicle capable of launching a satellite into orbit. At the end of his speech he made a formal call to accept his offer to build and launch a series of satellites, including one with animals into space, and for the Academy to establish a commission to carry out this goal. With a host of supporters at the meeting, there was little resistance, and the proposal was accepted. At Korolev's recommendation Keldysh, an individual with good connections to the Party leadership, was designated the Chairman of the commission. Korolev and Tikhonravov were to serve as his deputies. The date of launch was set between April and July of 1957, in time for the beginning of the IGY. An elaborate scientific programme was drawn up which included the study of the ionosphere, cosmic rays, the Earth's magnetic fields, luminescence in the upper atmosphere, the Sun and its influence on the Earth and other natural phenomena. The detailed development of a scientific programme was left in the hands of the two existing commissions of the Academy headed by Blagonravov and Leonid I. Sedov respectively [22].

The combination of Korolev's managerial genius and Tikhonravov's technical acumen proved to be the force that affected the course of humankind's departure from Earth.

A few months later on 30 January 1956, the Central Committee of the Communist Party and the USSR Council of Ministers issued an official joint resolution (no. 149-88ss) approving this plan. As per Tikhonravov's previous computations, the mass of the satellite was limited to the range of 1,000 to 1,400 kg of which 200 to 300 kg would be scientific instruments. The first launch was slated for 1957 [23].

The satellite, known as the Object D, was the most well-known element of the original Tikhonravov report. The complex scientific observatory was eventually launched into orbit in May 1958 as Sputnik-3 [24]. The experience from the Object D project also significantly aided in the preparation of the first two Sputniks which were short-term interim efforts in 1957 [25]. As per Tikhonravov's original paper from 1954, the Object D itself was made in three different variants, the simplest being the one which was actually launched into space. Of the other two versions, one was to be equipped with an orientation system, and the other was to carry a biological payload. These two models, the Object OD-1 and OD-2 respectively were developed in 1956-58 to fulfil the original objectives from 1954. The OD-1 was the prototype of a military reconnaissance satellite intended to take photographs of the "probable enemy." Special recoverable cassettes with film were developed, the photography system itself being created by the S. I. Vavilov State Optical Institute [26]. This research was being carried out as early as April 1957, six months prior to the launch of the first Sputnik in October 1957.

The Object OD-1 was evidently abandoned by 1957-58 and the reconnaissance satellite effort was transferred to the Object OD-2 as a common spacecraft module which would serve both the reconnaissance satellite programme and the manned space effort. Although the OD-2 went through some major design changes in late 1958, the spacecraft that emerged from it went on to become the Zenit and Vostok spacecraft, possibly the two most important space projects in the early Soviet space programme.

Conclusions

The events that laid the groundwork for much of the early Soviet space programme raise some interesting points regarding the manner in which institutions operated at the time. Although satellite studies began as early as 1948, it took nearly a decade before the results of these efforts materialised. The delays can be attributed to three primary factors:

- The two main progenitors of the Soviet space programme were employed by two different organisations in different ministries, the Ministry of Armaments for Korolev's NII-88 and the Ministry of Armed Forces for Tikhonravov's NII-4. The institutional barriers between the two organisations clearly impeded fruitful work on satellites. Coordination of the satellite work was, at best, haphazard and without a singular purpose.
- There were major personal conflicts between the powerful individuals in each sector which served to hinder fruitful work. These included Korolev's vendetta against the NII-4 over a state award, Marshall Nedelin's disapproval of Academician Blagonravov, and NII-4 Director Nesterenko's damaging letter about Korolev's work.
- The primary goal of these institutes was not to engage in 'scientific' work but to augment the defence might of the Soviet Union. Thus every early effort from Korolev to interest the Soviet leadership in these projects met with failure. There was a remarkably profound concern, especially among military commanders that work on satellites would serve to divert resources from the ICBM programme.

One final theme that emerges from the early history of Soviet satellite research was that all of these ambitious proposals for satellites and human space flight originated not from the 'top-down' but rather from the 'bottom-up.' In hindsight almost all Soviet space projects through its 40 year history were proposed due to the foresight and ideas of its middle level Chief Designers and did not emerge from macro-level discussions at the government level. The exceptions to the rule were the military space programmes, but even in that field, there were a large number of projects such

as the anti-satellite system and the radar ocean reconnaissance system which originated from the suggestions of Chief Designers.

Both Korolev and Tikhonravov were visionaries. Unlike almost all the other prominent space designers such as Chelomey, Yangel, Reshetnev, Kozlov, Mishin and others, Korolev and Tikhonravov had an ideal of space exploration from their years as young amateur enthusiasts. This youthful enthusiasm was the source which flowered into full-fledged work which literally changed the workings of Soviet science. The combination of Korolev's managerial genius and Tikhonravov's technical acumen proved to be the force that affected the course of humankind's departure from Earth. And as the events of the late 1940s and early 1950s attest, their efforts began long before the launch of the lone Sputnik on 4 October 1957.

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11. Raushenbakh, op. cit., p.519; Golovanov, op. cit., p.519. Also present were S.E. Khaykin, I.A. Kibel, astronomer B.V. Kukarin, and physicist S.N. Vernov. The latter was closely involved in scientific suborbital launches in the 1940s and 1950s.
12. Raushenbakh, op. cit., p.209; Golovanov, op. cit., p.519.
13. Golovanov, op. cit., p.519.
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15. Raushenbakh, op. cit., p.209; Golovanov, op. cit., p.519; Ishlinskiy, op. cit., p.445; Yu.V. Biryukov, "Materials in the Biographical Chronicles of Sergey Pavlovich Korolev," in B.V. Raushenbakh, ed., Iz istorii sovetskoy kosmonavtiki: sbornik pamyati akademika S.P. Koroleva, Nauka, Moscow, 1983, p.233.
16. Raushenbakh, op. cit., p.5.
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20. Golovanov, "The Beginning of the Space Era," op. cit.; Ishlinskiy, op. cit., p.445. The final report was co-authored by Ilya V. Lavrov, an engineer at the OKB-1.
21. Ishlinskiy, op. cit., p.454; Golovanov, Korolev: fakty i mify, op. cit., pp.523-524; Golovanov, "The Beginning of the Space Era," op. cit. Others present were M. A. Lavrentiyev and G.A. Skuridin.
22. Christian Lardier, L'Astronautique Sovietique, Armand Colin, Paris, 1992, p.107; Golovanov, "The Beginning of the Space Era," op. cit. Blagonravov's commission was at the time directing the scientific investigations on board suborbital rockets, while Sedov's commission had recently been established as a public forum for Soviet scientists to discuss space exploration.
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24. There was actually a launch failure in April 1958 on the first try to launch the Object D. The second try in May with a back-up article was more successful.
25. For a detailed exposition of hte events in 1955-57 covering the genesis of the first Sputnik satellite, see Asif Siddiqi, "Korolev, Sputnik, and the International Geophysical Year", presented at "Reconsidering Sputnik: Forty Years Since the Soviet Satellite", Washington, DC, September 30-October 1, 1997.
26. S.P. Korolev, "Proposal for an Oriented Artificial Earth Satellite" (in Russian) in Keldysh, op. cit., pp.373-374.

This article under its original title,"The Road to Object D", was winner of the Robert H. Goddard Historical Essay Contest for 1997.

Part 1 appeared in the previous issue of ***Spaceflight***, pp.334-337.

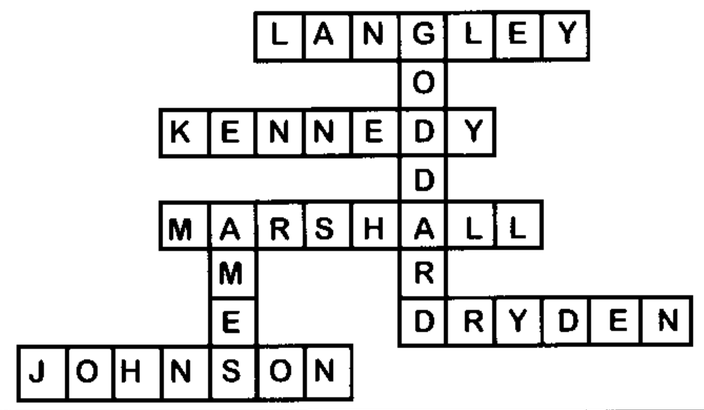
A Partial List of the Artefacts in the "Space Race" Exhibit

(See p.372.)

V-2 missile
WAC Corporal rocket
Jupiter-C launch vehicle
Scout-D launch vehicle
Minuteman III missile and technical manual
Sputnik arming key
Ivan Ivanovich mannequin
Sergei Korolev's slide rule
Yuri Gagarin's cosmonaut and Communist Party ID cards
John Glenn's Mercury flight suit, helmet, gloves and boots
Konstantin Feokistov's flight suit
Voskhod 2 airlock, trainer
Aleksei Leonov's Berkut suit, training
N-1 rocket, 1:48 scale model
Krechet lunar suit, prototype
CORONA KH-4B camera and film-return capsule
Salyut film return capsule
Merkur spacecraft (Kosmos 1443)
Skylab orbital workshop and solar array wing
Apollo Spacecraft
Apollo-Soyuz docking module
Soyuz spacecraft and retrorocket
X-20 Dyna-Soar model
Various space shuttle concept models
Anatoly Berezovoy's Salyut 7 pressure suit glove
Norman Thagard's Sokol launch/reentry suit and gloves
Soyuz TM-10 landing module
Hubble Space Telescope test vehicle and support stand

'US Centres' Competition Winner

The winner to whom a book prize will shortly be dispatched is Mr G. Buckley, UK.



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Renewal forms have now been despatched to all BIS members. Please help by remitting as soon as possible. This will ensure that monthly publications will continue to be received without delay.

Please give this matter your prompt attention. We look forward to hearing from you. **Shirley Jones, Executive Secretary**