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25 JANUARY 1980 FOUO 1 OF 4

JPRS L/8883

25 January 1980

Translation

S. V. Il'yushin: Scientist and Designer

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S. V. IL'YUSHIN: SCIENTIST AND DESIGNER

Moscow UCHENYY I KONSTRUKTOR S. V. IL'YUSHIN in Russian 1978 signed to press 4 Dec 78 pp 1-207

Book edited by A. Ya. Kutepov et al., "Nauka" Publishers, 20,000 copies

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[II - USSR - FOUO]
[III - USSR - 4 - FOUO]
[III - USSR - 38 - FOUO]

PUBLICATION DATA

English title	:	S. V. IL'YUSHIN: SCIENTIST AND DESIGNER
Russian title	:	UCHENYY I KONSTRUKTOR S. V. IL'YUSHIN
Author (s)	:	
Editor (s)	:	A. Ya. Kutepov et al
Publishing House	:	Nauka
Place of Publication	:	Moscow
Date of Publication	:	1978
Signed to press	:	4 Dec 78
Copies	:	20,000
COPYRIGHT	:	Izdatel'stvo "Nauka", 1978

INTRODUCTION

[Text] The name of the prominent aircraft designer, Il'yushin, became well known in the 30's, years which were noted in the history of domestic aircraft production for the swift development of all types of aircraft equipment. He acquired a widespread reputation after the CDB-26 [Central Design Bureau] aircraft he designed set a number of world records and accomplished a long-range, nonstop flight from Moscow to North America. It was noteworthy that all the records were not set by an aircraft specially built for this purpose but by one of the operational aircraft.

The beginning of S. V. Il'yushin's creative work is linked to the development of fundamentally new types of aircraft: the IL-2 ground attack aircraft and the IL-4 long-range bomber. The former was a new type of combat aircraft which was able to accomplish tactical missions which were not typical of the aircraft in service with the Soviet and foreign air forces at that time. It naturally brought about new tactics for the combat operations of ground attack aviation.

The development of the design for the LRB-3 [long-range bomber] (IL-4) was based on new engineering concepts in aerodynamics, design and technology. It was one of the aircraft which caused the next qualitative leap forward in the development of domestic aviation. With its significantly smaller dimensions and weight, the IL-4 had a greater range and speed than its predecessors; in maneuverability, it could perform aerobatic maneuvers, such as the normal inside ascending loop.

S. V. Il'yushin's design bureau built numerous different aircraft and various modifications to them. They included the IL-2, IL-4 and IL-28 military aircraft and the IL-12, IL-14, IL-18 and IL-62 civilian aircraft, which were not only stages in the creative work of Il'yushin's design organization but also in the development of domestic aircraft production. In their technical specifications and economic performance, reliability and comfort, they were not inferior to the best foreign aircraft in the corresponding classes, while the IL-2 knew no equals. It was not by accident that a memorial to it was built on the approaches to Moscow, in whose defense it played such an important role.

The following traits were typical of S. V. Il'yushin: a search for simple and rational solutions to various design problems, a desire to create the most efficient aircraft based on a harmonious combination of all parameters and the development of aircraft designed for mass production and large-scale operational use. S. V. Il'yushin believed that it was not enough to create an improved aircraft; it was necessary to ensure the production and operational technological efficiency of its design as well as simplicity in controlling and handling it.

S. V. Il'yushin's success was achieved due to his solution of engineering problems based on the latest scientific achievements, his bold introduction of the new and, which is extremely important, his exceptional farsightedness.

It is well known that a relatively long period of time passes between the appearance of a new idea or new theoretical development and the creation of engineering systems. The same thing happens with the introduction of new materials or new industrial processes. Therefore, when developing designs, among the numerous other problems which must be resolved is the one of selecting between the tried and true, on the one hand, and the new and progressive, on the other. Determining the degree to which the realization of various innovations is feasible while a specific aircraft is being created is a rather complex task. S. V. Il'yushin's scientific erudition, designer's intuition and invariable sense of reality helped him solve this task.

In solving many of the difficult problems, S. V. Il'yushin proceeded from the requirement for compromises in resolving planning and design problems and for an optimum combination of parameters. He was the enemy of preconceived routines and obsessions and also of repeating previously selected configurations if better solutions could be found for new conditions.

S. V. Il'yushin had many students and followers who make up the backbone of his design organizations. Sergey Vladimirovich developed numerous design principles and methods and created his own style of design and his own school of aircraft production.

We should also point out something else. The organizational and engineering methods and work style and, perhaps, the traditions of many aviation plants and operational organizations were molded under the influence of S. V. Il'yushin's engineering policy which was reflected in his aircraft designs, blueprints and other technical documentation; he attached exceptional importance to the development of these documents.

Sergey Vladimirovich Il'yushin was a prominent aircraft designer and scientist and he occupies a worthy place in the history of aviation. During each phase of aviation development, his ground attack aircraft, bombers and airliners were innovations in engineering thinking. Sergey Vladimirovich made an invaluable contribution to the country's defense, the development of air transport and progress in the engineering sciences and technology of the aircraft industry. The publication of this book by the USSR Academy of Sciences, a book devoted to Academician S. V. Il'yushin, is another recognition of his great talent and his exceptional services to the motherland.

This book tells about the director-general's creative records, his aircraft and the environment in which his work took place, beginning from his days as a student at the Academy imeni Professor N. Ye. Zhukovskiy where he not only studied but also built gliders. V. S. Pyshnov's article is devoted to this period and to the development of the academy itself. V. V. Struminskiy devoted his article to the joint work between Il'yushin and the Central Aero-Hydrodynamics Institute in the field of aerodynamic design, especially during the postwar period.

Supplementing V. S. Pyshnov's article, O. K. Antonov has reflected Il'yushin's work as one of the leaders in gliding during its initial period of development.

G. V. Novozhilov, A. I. Makarevskiy, Ya. A. Kutepov and R. I. Rokityanskiy devoted their articles to the designer-general's creativity and his development of the large family of IL aircraft.

A. S. Yakovlev's article vividly describes S. V. Il'yushin's character traits as the creator of fundamentally new aircraft and as the manager of a large creative group.

V. M. Sheynin's article tells about the design group established by S. V. Il'yushin and about the school he founded.

V. F. Leont'yev tells about the historical phase in aircraft development when S. V. Il'yushin created his group. He has devoted his article to the famous galaxy of Il'yushin designers.

An analysis of the historical aspect of the creative process of aircraft design is provided by A. A. Badyagin and A. A. Maslennikov.

The problems of engineering and combat efficiency of aircraft and the operational efficiency of the civilian aircraft designed by S. V. Il'yushin, as well as the problems of testing these aircraft, are covered in the articles by A. N. Yefimov, A. V. Minayev, A. N. Ponomarev, R. V. Sakach and N. V. Shklyarov.

Thus, this anthology shows S. V. Il'yushin's multi-faceted, creative work and provides an analysis of the engineering efficiency and effectiveness of the aircraft he designed. The authors--specialists in various fields of science and engineering--provide an evaluation of the advantages of his aircraft. Although the articles sometimes cover the same aircraft, they cover them in different ways and from various points of view.

The editors considered it advisable to include selected articles by Academician S. V. Il'yushin in this anthology; these articles were published at different times in the magazine AVIATSIYA I KOSMONAVTIKA and the newspaper PRAVDA. These articles are interrelated in subject matter and they set forth, in sequence, the developmental history of the aircraft designed by S. V. Il'yushin and the creative work of the group which developed them.

The editors express their gratitude to A. A. Kobzarev, doctor of engineering sciences, professor, State Prize Winner and Hero of Socialist Labor, and M. M. Kulik doctor of engineering sciences--who took upon themselves the work of reviewing the manuscript--and also all our comrades who took part in preparing this anthology for the press.

PART I. ACADEMICIAN S. V. IL'YUSHIN'S CREATIVE WORK AND THE AIRCRAFT HE DESIGNED

CHAPTER 1

SERGEY VLADIMIROVICH IL'YUSHIN

A. S. Yakovlev, designer-general, academician, twice-honored Hero of Socialist Labor and Lenin and State Prize Winner

I met Il'yushin in the fall of 1923 at the glider competitions in the Crimea. At that time, he was a student at the Air Force Academy and the designer of one of the first Soviet gliders, Workers' School Student, while I was a Moscow school student, hopelessly infatuated with aviation.

I don't know by what signs Sergey Vladimirovich saw a future designer in me, a 17-year-old young man, but I am greatly obligated to his assistance and continual attention. During a period of four decades, Il'yushin and I were very close, not only as professional colleagues but also simply as great friends.

Once, at the beginning of our friendship, I was very concerned about him. In 1935, our plant built a three-seat liaison aircraft which was good-looking, comfortable and easy to control. This aircraft participated in a Sevastopol'-Moscow sports flight and received a prize.

Il'yushin liked the aircraft a lot. At that time, his vehicles were not being built in Moscow. He frequently had to fly out of Moscow. Flying himself in a slow-moving PO-2, Sergey Vladimirovich lost a lot of time; therefore, he requested that we give him our aircraft.

Several times, upon returning to Moscow, Sergey Vladimirovich thanked us for the aircraft. But, once, in the evening, a call came from Ryvicher, the airfield controller, and he said:

"We just received a report that the designer Il'yushin was smashed up in a red aircraft enroute to Moscow... Isn't that your aircraft?" (The aircraft I gave to Sergey Vladimirovich was red.) I froze from fright. I was upset. Il'yushin, smashed up! What had happened?! Finally, the report arrived: the aircraft was smashed up but the pilot was alive.

I saw Il'yushin several days later. His head was bandaged up. With a feeling of inexpressible joy, I embraced my friend. "Sasha," he said, "I don't have any grudge against you. It's a remarkable aircraft but it turns out that the motor doesn't work without oil; this 'small detail' should not be overlooked." The accident was the mechanic's fault; he forgot to fill the aircraft with oil. Il'yushin had to put the aircraft down at night in unfamiliar surroundings. Sergey Vladimirovich had a scar on his forehead for life.

Sergey Vladimirovich was a man with marvelous good fortune. In his youth, he was a peasant shepherd in one of the northern provinces of central Russia and then he was a soldier in the tsarist army.

After watching the flights of the first Russian aviators at Petersburg Airfield where Aviation Week was in progress, he became a fan of aviation and decided to learn to fly at any cost. Il'yushin achieved his dream and became a pilot. In 1918, he became a communist. S. V. Il'yushin was an active founder of the Red Air Force, a commissar of an aircraft repair train at the front during the Civil War and, finally, in 1922, a student at the recently established Air Force Engineering Academy imeni Professor N. Ye. Zhukovskiy. An enormous amount of work was required for him, a man with hardly any education, to get ready to enter the academy within a short period of time; but, he successfully passed the competitive entrance examination.

Like many other students at the academy, Il'yushin combined his studies with practical, voluntary work on building gliders of his own design: the Mastyazhart [Concentrated Heavy Artillery], the Workers' School Student and the Moscow. These gliders participated in the glider competitions at Koktebel' on numerous occasions. Upon completing the academy, he served in the Air Force and, at the beginning of the 30's, S. V. Il'yushin left the Air Force for a design job, which had been his cherished dream for a long time. From that time forward, he became the designer of the world reknown aircraft which bear his name.

The year 1931, when he was in charge of the Central Design Bureau, marks the beginning of Sergey Vladimirovich's design work. In 1933, he was the chief designer of the independent Experimental Design Bureau which was organized according to a governmental decision. The creative work of the Experimental Design Bureau developed in three basic directions: the development of bombers, ground attack aircraft and airliners.

The first aircraft built by Il'yushin's design bureau was the CDB-26 long-range bomber. During aircraft testing, good flying performance was obtained; this performance was not inferior to the performance of the same type of foreign bomber. In his work to improve this model, Il'yushin developed several versions: the LRB-3 and the LRB-3F; the latter was called the IL-4.

The LRB-3 was built in the beginning of 1936. The first flight took place in March of the same year. The flight tests were conducted by test pilot V. K. Kokkinaki. On 1 May, the LRB-3 was among the aircraft which took part in the flyby. While flying the LRB-3 over Red Square, Kokkinaki did several inside ascending loops; this made a very strong impression on everybody. Nobody believed it was possible to do acrobatics in a large two-engine bomber.

The next day, 2 May, Il'yushin and Kokkinaki were summoned to the Kremlin. Party and government leaders congratulated the designer and pilot, questioned them thoroughly about the aircraft and made a decision to put it into series production.

Of course, the inside loops over Red Square were not the decisive factor in putting the LRB-3 into series production. This aircraft had a higher speed than the similar-role Tupolev LRB-2, which had recently been put into series production. The LRB-2's speed was 343 km/hr while the LRB-3's speed was 403. As a result, production of the LRB-2 stopped and the LRB-3 went into mass production.

To check out the range, V. K. Kokkinaki and A. M. Bryandinskiy, his navigator, made a long-range, nonstop flight in the LRB-3 with a full combat load along the route Moscow-Baku-Moscow. The next day, Kokkinaki was invited to the Kremlin where he reported on the details of the flight. After this flight, the LRB-3 gained a firm reputation as an outstanding long-range bomber.

While continuing to develop this successful design, Il'yushin's Experimental Design Bureau group produced a new version of the aircraft in 1938--the LRB-3F. In 1940, with the designation IL-4 and equipped with more powerful engines and enhanced armament, this aircraft replaced the LRB-3, which had been created in 1936, in series production.

But, it was another of his combat aircraft which undoubtedly brought true fame to S. V. Il'yushin--the IL-2 ground attack aircraft.

Prior to this, unsuccessful attempts to develop a ground attack aircraft had been undertaken on numerous occasions in the pre-war years, both in our country and abroad. Il'yushin was able to solve this problem. Essentially, ground attack aviation--as a new branch of aviation which cooperated closely with land forces--was established on the basis of the aircraft designed by S. V. Il'yushin.

The large role of the IL ground attack aircraft in defeating the fascist armies was pointed out on numerous occasions both in the Soviet and in the foreign press. This was the most mass-produced aircraft in the Great Patriotic War.

The IL-2's destiny was astonishing.

At first, Il'yushin made a two-seat prototype version of the IL-2. The aircraft crew consisted of a pilot and a gunner-radio operator who, sitting behind the pilot, took care of radio communications and, with the machine gun mount at his disposal, he defended the aircraft against enemy fighter attacks from the rear.

A powerful forward-firing cannon weapons system was installed on the IL-2. Therefore, it did not have to fear an attack from the front either.

This aircraft underwent State Tests and was put into series production before the war. However, while series production was in progress, Il'yushin was forced to convert the two-seat IL-2 ground attack aircraft into a single-seater. The military believed that the IL-2's speed and ceiling were too low. In their opinion, by eliminating the second compartment with the gunner-radio operator and the defensive machine gun, it would be possible to lighten the aircraft, enhance its aerodynamics and obtain a certain increase in speed and ceiling.

However, from the first days of the war, the single-seat version of the IL-2, without the defensive machine gun in the rear, was defenseless against enemy fighters. The Germans noticed this weak spot in the ground attack aircraft. Ground attack units began to sustain heavy losses during the first months of the war.

Then, in the beginning of February 1942, Il'yushin and the People's Commissar were summoned to a meeting where the issue of returning to the two-seat version of the ground attack aircraft was raised. Moreover, they agreed with the designer that the ground attack aircraft did not need a high speed and high ceiling since the lower it flew the greater the damage it would inflict on the enemy.

Il'ysuhin asked for three days to think it over. Three days later he was summoned again. Il'yushin brought a blueprint and reported that an extremely successful solution had been found: almost without any alterations and without any loss in scheduled production of the aircraft at the series plants, it would be possible to restore the second compartment for the gunner-radio operator and install the machine gun to fire at enemy aircraft in the rear hemisphere. He promised to have the first aircraft ready by 1 March and the second by 10 March. The two-seat version of the IL-2 ground attack aircraft was approved and the decision was made immediately to put it into series production, even before the aircraft was flight tested.

From then until the end of the war, the ground attack aircraft were produced in the two-seat version. Their losses in air battles sharply declined.

While developing the IL-2, Il'yushin was able to resolve many engineering problems for the first time, including using armor as a load-carrying structure, finding the technology to make the armored skin with highly cambered contours, etc.

The story of the IL-2's development clearly shows the exceptional personal qualities of its creator: the designer's talent, his conviction and persistence in achieving the assigned goal and his exceptional gift of foresight.

In spite of criticism from several shortsighted specialists, who believed the Il-2's speed and ceiling was not sufficient, Il'yushin correctly saw its primary role and he established the "character" of the ground attack aircraft. PRAVDA wrote in this respect: "Il'yushin's aircraft is not just an achievement of aviation science. It is a remarkable tactical discovery. It is based on an idea which is profound and accurate."

There was a total production of more than 41,000 IL-2 and IL-10 ground attack aircraft. They were the most mass-produced aircraft in our Air Force.

During the war, the primary efforts of the Experimental Design Bureau were thrown into improving the ground attack aircraft; but, Il'yushin also continued his work on developing new bombers. Thus, in 1943, the new twin-engine IL-6 bomber was tested. This aircraft was somewhat larger than the IL-4 and had a more powerful armament system. However, the ACH-30V diesel aircraft engines used on it and designed by A. D. Charomskiy, with all their positive data especially in economy, were not brought up to an operational status and the aircraft was therefore not built on a series basis.

At the end of the war, Il'yushin's Experimental Design Bureau began its work to design the first jet bombers. In 1946, the IL-22 underwent flight testing. This experimental aircraft with four TR-1 turbo-jet engines designed by A. M Lyul'ka was used to check out certain design decisions and to accumulate the experience necessary to develop future designs.

The IL-28 was the first Soviet tactical jet bomber which entered service with the Air Force. Like all Il'yushin aircraft, the IL-28 was distinguished by its tactical and flying performance and by its technology, which was quite well adapted for large-scale series production. Suffice it to say that the labor intensiveness for building this 22-ton bomber approximated the labor intensiveness for building fighters.

The IL-28 tactical bomber was modified a number of times and the following were developed: the IL-28R reconnaissance aircraft, the IL-28U trainer and the IL-28T torpedo bomber. However, the IL-28, just like the LRB-3 and the IL-2 and later the IL-18, did not immediately receive recognition.

In subsequent years, the IL-46 and IL-54 were built and tested; they continued the line of Il'yushin bombers. The IL-54 bomber had a swept wing and bicycle landing gear. The IL-40 jet ground attack aircraft was produced and successfully underwent State Tests at approximately the same time.

For various reasons, reasons which were not always justified, these new aircraft, just like the IL-6 and IL-22 which were discussed above, were not put into series production. But, the valuable experience of working on them provided invaluable experience for the designer in his future progress; soon afterwards, this was very convincingly confirmed by practical experience.

The third direction in S. V. Il'yushin's design work was, as already mentioned, the development of airliners.

By the end of 1943, things were proceeding successfully at the front. Our aircraft had complete air supremacy. The aviation industry was working at full capacity and aircraft production continued to increase. The urgency in supplying combat aircraft for the front had been eliminated.

Now, they began to talk about transports and airliners. It was now possible for our industry to accomplish this task without any detriment to combat aircraft.

Il'yushin was already working on the two-engine IL-12 transport-airliner; a prototype of this aircraft had been built with diesel engines. There was a requirement to develop, as quickly as possible, an aircraft which was able to fly faster and further than the LI-2 airliner which was the Civil Air Fleet's primary aircraft at that time.

In this connection, we and the People's Commissar were summoned to the Kremlin on a January evening in 1944. We were asked about a passenger express capable of carrying 10-12 passengers 4,000-5,000 kilometers nonstop. We were asked whether it would be possible to convert any of the current bombers for this purpose. It was difficult to say right offhand whether the fuselage of a bomber could accommodate 12 passengers and provide them the comfort necessary for an extended flight (10-15 hours). Therefore, we requested time to think it over.

We gave a report on Il'yushin's work on the IL-12. The development of the IL-12 was approved but they still asked us to think about the possibility of using Yermolayev's ER-2 bomber.

As is well known, soon afterwards, the IL-12 went into mass production, but not with the diesel engines--with two ASH-82 air-cooled engines. As far as converting the ER-2 into an airliner goes, it did not seem advisable.

As a result, during the first postwar years (beginning in 1947), the twin piston-engine IL-12, and later the IL-14 (a modification of the IL-12), plied their way on USSR civil air routes. For their time, these were outstanding aircraft, extremely economical and very safe in flight.

After the IL-12, Il'yushin's design bureau developed a new, large airliner, the four piston-engine IL-18. Vladimir Kokkinaki tested the aircraft; he gave the aircraft's flying performance a very high rating. But, the first version of the IL-18 did not go into mass production. It was believed that Aeroflot did not require any large airliners at that time.

By the mid-50's, it had become obvious that piston aircraft had had their day and the future of civil aviation belonged to turbine engine aircraft.

However, the first Soviet TU-104 airliner with the AM-3 turbo-jet engine designed by A. A. Mikulin was only a successful modification of a military aircrart--the TU-16 bomber. It could not completely satisfy Aeroflot's requirements, primarily in economy.

The state of the art in aircraft engine construction for those years did not make it possible to develop sufficiently economical engines with a pure jet thrust; therefore, the turbo-prop engines were believed to be the most efficient for civil aviation.

The issue of the requirement to develop civilian aircraft for Aeroflot's routes, aircraft with all the specific special features inherent in airliners, was discussed at a governmental meeting in which the aircraft designers O. K. Antonov, S. V. Il'yushin and A. N. Tupolev participated. A requirement was advanced on the feasibility of using the aircraft in a transport version without any serious modifications,

Such an aircraft could undoubtedly be built; however, its performance as an airliner would inevitably be degraded. Sergey Vladimirovich immediately stated that he thought it was not advisable to make a general-purpose aircraft. A mass-produced airliner must be a special-purpose aircraft--only then would it be possible to avoid large losses during its operational use. Il'yushin firmly stood his ground and finally refused to make such a general-purpose aircraft since he believed it was a big mistake.

A. A. Antonov met these requirements halfway--After this, the development of the aircraft was assigned to Antonov's Experimental Design Bureau. However, they were convinced by Sergey Vladimirovich's case and the assignment to built a special-purpose airliner was given to Il'yushin's Experimental Design Bureau.

Soon afterwards, two new aircraft arrived almost simultaneously at the airfield for testing: the IL-18 and the AN-10. The IL-18 was a 100-seat airliner with four AI-20 turbo-prop engines designed by A. G. Ivchenko--it successfully passed all the tests and became Aeroflot's primary, most high-volume aircraft. The correctness of Il'yushin's ideas on the need to develop a special-purpose airliner without any attempt to combine the incompatible was completely corroborated. This small but principled episode is all Il'yushin. His conviction that he was right and his uncompromising nature in questions of principle did not permit him to agree with the requirement to develope a general-purpose aircraft.

Il'yushin's aircraft brought him world-wide fame, aircraft like the IL-2 ground attack aircraft, the IL-4 bomber, the IL-12 and IL-14 airliners, the IL-28 jet bomber, the IL-18 trunk-route airliner and, finally, the intercontinental IL-62. Each of these aircraft did not immediately receive recognition and they were not put into service immediately; this only came about due to the designer's unbending will, persistence and conviction that he was right. Il'yushin's entire creative history provides the most convincing evidence that there is no victory without a struggle.

Then, in 1957, another IL-18 appeared--Il'yushin's first trunk-route airliner with turbo-prop engines; within a short period of time, it became the most high-volume aircraft in USSR civil aviation.

The IL-18 was produced in different versions: the IL-18A, IL-18P, IL-18V, IL-18D and IL-18E; it outlived the first-generation gas-turbine aircraft in series production, thereby proving the productive nature of the very idea of a special-purpose airliner, the idea which the designer used as the basis for the design.

The IL-62 and the IL-62M modification to it (accommodations for 198 passengers and a maximum range of 10,500 km), which became Aeroflot's flagship, were further stages in Il'yushin's creative work. It is noteworthy that even this very large aircraft has preserved that simplicity and ease of handling which are inherent in all the IL aircraft. This is one of the manifestations of S. V. Il'yushin's creative style, a style which is typified by his desire for an optimal design and his persistence in achieving maximum aircraft reliability and safety combined with a high level of economy or combat efficiency.

Designing any modern aircraft is a multi-faceted, creative process. It is distinguished from the creative work of the artist or writer by the fact that, in addition to a knowledge of the subject, a range of interests and, of course, talent, the production designer must also be a good production engineer. He must know how the design can best be accomplished in production.

The designer must also be able to manage the people who implement his ideas throughout all the stages of design, construction and testing since, in the final analysis, the success of the entire job does not just result from the design bureau manager's work but from the work of the entire group as a whole.

The designer must consider a multitude of various factors and be able to design economically, without any waste, by using just the amount of material required for operational endurance and convenience.

The designer must look for the simplist engineering solutions so that the manufacturer of aircraft requires minimal labor inputs. Such solutions are the result of persistent, painstaking work and they are not immediately clear and simple but only become so after long and frequently torturous attempts.

S. V. Il'yushin is a master of simple solutions. All of his aircraft testify to this fact. It is well known that it is difficult to develop the simple.

The designer must be firm, strong willed and able to patiently and persistently overcome the obstacles on the way to his assigned goal. The designer must not be self-satisfied or conceited. And, of course, the designer must be a dreamer. It is in dreams that new ideas are born. Fulfilling a dream is the greatest meaning in life for a Soviet man and especially for a designer.

The combination of traits required for a great designer are not frequently encountered in a single person. Designer-General and thrice-honored Hero of Socialist Labor Sergey Vladimirovich Il'yushin was among the few who possessed all these traits.

CHAPTER 2

S. V. IL'YUSHIN'S ROLE IN THE DEVELOPMENT OF DOMESTIC AVIATION

G. V. Novozhilov, designer-general, doctor of engineering sciences, Hero of Socialist Labor and Lenin Prize Winner

The famous group of Il'yushin designers has been in existence for four decades. Throughout this time, the skies of all the earth's continents have been traversed by the aircraft developed by the prominent aircraft designer, Academician Sergey Vladimirovich Il'yushin, thrice-honored Hero of Socialist Labor, Lenin and State Prize Winner and colonel-general of the Aviation Engineering Corps.

First, I would like to point out that an aircraft designer's work is not simply free and easy creativity and the flight of thought based on scientific and technological achievements and directed at designing aircraft; it is primarily the ability to combine design feasibility (in the broad sense of the word) and the missions which arise during the development of a new aircraft.

The high degree of efficiency of the IL aircraft specifically show that an in-depth understanding of the purpose for developing an aircraft made it possible for Il'yushin to discover correct and optimal planning and design solutions which ensured a long flying life for his aircraft.

Each newly designed aircraft which is intended to accomplish specified missions must meet new, higher requirements. Aircraft dimensions, configuration, layout, design and, finally, all its systems must meet these requirements to the maximum possible extent. The ability to achieve a simple engineering solution to these complex and at times contradictory problems made it possible for S. V. Il'yushin to develop aircraft which have played a significant role in the development of the USSR Air Force and which have ensured the accomplishment of a large share of the civil air transport. These aircraft occupy a worthy place in the history of domestic aviation.

Each designer usually has his own special field. There are numerous different types of aircraft in aviation and the development of each type has its own special features. The group which was established and molded by S. V. Il'yushin can rightfully be called a multi-skilled aviation group. Ground attack aircraft, bombers, airliners and numerous modifications to them--this is what Academician S. V. Il'yushin and his group worked on for many years.

As soon as military aircraft appeared, the first attempts were made to use them to counter enemy land forces. For this purpose, various types of aircraft were used. However, the idea gradually arose of developing a special-purpose, low-altitude aircraft designed to participate in operations over the battlefield, an aircraft which would make it possible to ensure a high degree of accuracy in aiming at and, consequently, a high degree of effectiveness in destroying enemy land forces.

The ground attack aircraft was such a special-purpose aircraft. A high degree of effectiveness in destroying ground-based targets combined with maximum invulnerability from the ground and air--this is the brief formula (far from complete) for the ground attack aircraft. In spite of the fact that it was obviously adviseable to create such an aircraft, there was no serious experience in designing ground attack aircraft in the practical activities of world aircraft production until the 30's. At various times, individual attempts were made to solve the problem of developing a ground attack aircraft; but, only experimental aircraft appeared and they did not become widespread due to numerous deficiencies.

The solution to the problem of developing a ground attack aircraft encountered a number of difficulties. The trade-offs were too high: destroy with maximum effectiveness but remain invulnerable to all types of weapons which might be employed against you. The ground attack aircraft was a direct participant in the land battle; it would undoubtedly feel the effectiveness of all the weapons currently in service with enemy infantry and mechanized units.

The problem of defending the aircraft took on the utmost importance, no less important than its ability to destroy targets. This may sound somewhat paradoxical but it was precisely in the feasibility of protecting the aircraft and of ensuring its operational survivability that the designer encountered his primary difficulties.

Aircraft designers understood the requirement for armor protection of the crew and vital aircraft parts long before the idea appeared to develop a completely armored ground attack aircraft.

Sergey Il'yushin

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1. S. V. Il'yushin and the primary personnel of his initial design bureau (1942). From left to right: First row--V. M. Sheynin, D. V. Leshchiner, A. V. Sovetova, S. V. Il'yushin, A. S. Zhadayeva; second row--M. R. Bezdetko, S. N. Chernikov, V. M. Germanov.

2. S. V. Il'yushin among the supervisory personnel of the Experimental Design Bureau (1948). From left to right: Seated--V. A. Fedorov, G. M. Litvinovich, Ye. I. Sankov, V. A. Borog, S. V. Il'yushin, V. N. Bugayskiy, A. Ya. Levin, M. F. Astakhov; standing--D. A. Polikarpov, B. V. Pavlovskiy, N. F. Zotov, S. N. Chernikov, P. N. Nistratov, N. I. Maksimov, D. I. Koklin, D. V. Leshchiner.

M. I. Kalinin awards the Order of Lenin and the Hammer and Sickle Gold Medal to S. V. Il'yushin.

1.

2.

Aircraft Industry Designer-Generals.

1. From left to right: S. A. Lavochkin, A. N. Tupolev, A. S. Yakovlev, A. I. Mikoyan, S. V. Il'yushin.

2. From left to right: G. T. Beregovoy, S. V. Il'yushin, G. V. Novozhilov.

The first attempt to protect the pilot goes back to 1911; this attempt was made by the Italians. Then, the Russian aircraft designer I. I. Sikorskiy put armor on the Il'ya Muromets aircraft and D. P. Grigorovich put armor on the M-9 flying boats. After World War I, designers from American and German companies took up the armor problem. All of these were isolated attempts, i.e., they were of an individual nature and did not lead to an overall solution to the problem. The armor was either too heavy or (at the weight which the aircraft could lift) ineffective.

However, the idea of developing a ground attack aircraft continued to bother designers. Thus, D. P. Grigorovich built the LGA light ground attack aircraft and S. A. Kocherigin and M. I. Gurevich worked on the HGA-3 heavy ground attack aircraft. In 1930, A. N. Tupolev's design bureau developed plans for the ANT-17 (HGA-B and HGA-1) and ANT-18 heavy ground attack aircraft. The use of armor was designed into these aircraft; it protected the crew and partially protected the engines and radiators. These designs were not implemented. The attempt to convert the R-3 into a ground attack aircraft was also unsuccessful. All of these were heavy aircraft and their speed did not exceed 250 km/hr.

The job of designing a ground attack aircraft was assigned to S. V. Il'yushin's Central Design Bureau.

The development of a ground attack aircraft which had effective offensive and defensive combat weapons systems combined with a high degree of survivability was truly a complex problem. It was necessary to find optimal trade-offs between speed and maneuverability, range and bomb load, offensive weapons systems firepower, weapons for self defense and invulnerability.

The optimal trade-off between these characteristics for a future ground attack aircraft would only be possible when the three primary, especially complex design problems were resolved: aerodynamics, overall configuration and weight. These problems could not be satisfactorily resolved without an understanding of future aircraft tactics. It is well known that, to a significant extent, tactics are generated by the appearance of a new type of weapon. Consequently, while creating a ground attack aircraft, it was necessary to forecast the aircraft's tactical capabilities to a certain extent and the methods for employing it in combat operations.

The same question continually appeared before the designers: how to put an armored aircraft into the air without any detriment to its basic combat performance.

The answer and solution were provided by S. V. Il'yushin. The answer was simple and unconventional. Simplicity in resolving a problem is always difficult but the ability to find a simple solution which made it possible to manage the entire complexity of an engineering problem was the talent, the style of S. V. Il'yushin, designer and scientist, engineer and creator of aircraft equipment.

The armor was incorporated into the load-bearing structure of the aircraft. It replaced the framework and skin of the entire forward and rear part of the fuselage. The engine, cockpit, radiators and other structural elements were built into the contours of the armor.

This is how the armored hull--the most important part of the structure--of the IL-2 was designed. This is what made it possible to develop the ground attack aircraft, a qualitatively new type of combat aircraft which gave a brilliant showing on the battlefields of the Great Patriotic War.

The idea is the basis for everything new. But, it must be implemented. It is not enough to generate an idea; it is not enough to develop the lines and dimensions of a design. It is necessary to incorporate them in metal.

The development of an armored hull was complicated by the requirement to shape comparatively thick steel sheets into a double curvature. The latter was required to ensure good aerodynamic properties and to increase protective characteristics (the greater a shell's angle of impact with the armor, the lower the kill probability).

This complex problem could not be solved without in-depth study. The selection of the armor was highly significant. They settled on a composite armor which had dissimilar mechanical properties throughout its depth: a high degree of hardness in the outer layer, an average degree of hardness in the intermediate layer and a low degree of hardness (but, a high degree of tensile strength) in the inner layer. As shown by studies, this armor was better than homogeneous (uniform) armor; it withstood the destructive effects of small caliber anti-aircraft, small arms and machine gun weapons. When shells struck the hard, outer layer, they broke up, while the tensile strength of the inner layer did not allow the armor to split.

The development of an armored hull caused a large number of engineering problems. The fact was that the steel armor was barely machineable and it buckled while hardening. The manufacture of large-scale, streamlined, complex structures from 4-6 mm, and even 8 mm thick sheets of armor was only possible after the special technology for isothermal hardening, combined with stamping, was developed and put into production.

The difficulties were surmounted and the IL-2 was built. S. V. Il'yushin's ability to see the main issue and his ability to talk with people in various fields (metallurgists, metal scientists and technologists in various occupational areas) as equals led to success. His erudition as a scientist, experience as a designer and fervid loyalty to the job assigned by the party and government overcame all the obstacles. As always in a new undertaking, there were skeptics. "Your armor is thin," they told Il'yushin, "it cannot withstand the weapons which enemy land forces will use against the ground attack aircraft."

While developing the IL-2, S. V. Il'yushin was the first to understand that the performance of the armor protecting vitally important aircraft areas was not only dependent upon its thickness but also upon other factors. The most important factors were the sharp angles of impact between the projectile's warhead and the armor. The streamlining which determined the shape of the armored hull played a positive role in this area. As S. V. Il'yushin anticipated, the smooth body contours and the relatively high speed increased the performance of the "thin" armor.

By the beginning of the Great Patriotic War, only 249 IL-2's had been produced. They were used to equip the first ground attack regiments; in the winter of 1942, powerful strikes by ground attack aviation assisted in routing the enemy tank formations which had broken through to Moscow.

The unavoidable accuracy of crippling ground attack strikes against concentrations of enemy manpower, vehicles and reinforced pillboxes and the ability to fly in any weather and to strike targets from low-level flight or from a dive guaranteed an exceptional degree of operational performance in employing the IL-2 ground attack aircraft as a forward area weapons system.

The IL-2's operational efficiency was supplemented by its very high degree of reliability and survivability. Its survivability, which was proven by the operational employment of hundreds of aircraft, corroborated the optimal trade-offs conceived and implemented by S. V. Il'yushin, trade-offs between the aerodynamic configuration, flying performance, stability and controllability, on the one hand, and reserve power for the engine and a rational configuration of the armor plating for all vitally important aircraft parts, on the other hand.

In 1943, S. V. Il'yushin developed a new ground attack aircraft which was called the IL-10. It retained the same, overall configuration but had smaller dimensions and significantly better aerodynamic performance. It mounted new, more powerful engines designed by A. A. Mikulin. Its lower aerodynamic drag and enhanced power-to-weight ratio made it possible to increase its speed by 140 km/hr. Noticeable improvements were also made to the aircraft's maneuverability. In 1944, the IL-10 began to enter service with air units which were fighting on the front lines of the Great Patriotic War.

After the war, the piston-engine IL-20 and the twin jet-engine IL-40 ground attack aircraft were developed and built. The latter aircraft successfully passed the State Tests.

However, let's return to the initial period of S. V. Il'yushin's creative work--to the development of the CDB-26 long-range bomber. This aricraft differed significantly from its predecessors--the aircraft of the 30's, when domestic aviation was dominated by "heavy" multi-engine bombers with low wing loading, large dimensions and low speeds.

The outstanding flights and world records set in this aircraft by pilot V. K. Kokkinaki showed that the CDB-26 was able to meet the Air Force's requirements for a bomber aircraft in the 30's.

The LRB-3 and the LRB-3F (the IL-4) (modifications of the CDB-26) subsequently became the operational "work horses" of the Great Patriotic War.

The IL-4 carried 2500 kg of bombs and had a maximum range of 2800 km, a speed of 430 km/hr and a ceiling of 9700 m. The aircraft's maximum take off weight was 11,300 kg. The aircraft had a good defense against enemy fighters--four gun mounts. The IL-4 was used widely as a long-range aircraft, a tactical bomber and a torpedo bomber.

The LRB-3 was introduced into the inventory five years before the war began. This demonstrates that S. V. Il'yushin foresaw the future very well while developing aircraft. It can also be stated that Il'yushin's foresight was confirmed by the brilliant operational employment of his aircraft.

During the war, the more modern (and larger) IL-6 bomber with A4-30V diesel engines designed by A. D. Charomskiy was designed, built and tested. unfortunately, engineering difficulties made it impossible to build a reliable engine and this was an obstacle to putting the aircraft into series production.

After the war, the era of jet aircraft arrived. During its initial period of development in our country, two trends emerged. Some designers proceeded along the course of developing jet aircraft based on piston-engine aircraft; others proceeded to create completely new designs. Il'yushin selected the second route. He and his group designed and, in 1946, built the IL-22 experimental bomber with four TR-1 engines designed by A. M. Lyul'ka. The IL-22 was used to study numerous problems in jet aviation, problems whose solution was required for the development of new aircraft equipment in our country.

As a result of the planning and design studies, the experimental work and the IL-22 testing by the design bureau group, our country's first tactical jet bomber (of those which were introduced into the inventory), the IL-28 with two VK-1 engines designed by V. Ya. Klimov, was built and underwent State Tests within a short period of time.

While developing the IL-28--as with the other military aircraft--they were able to achieve a good combination of flying performance and flight handling characteristics and of offensive and defensive weapons and overall aircraft weight balance. While it had a high speed, the IL-28 was simple to control and had good stability and controllability. All of this was achieved on an aircraft with a thin, straight wing.

The selection of a straight wing for the aircraft brought about a number of objections from certain specialists who preferred a swept wing. Il'yushin compared the opponents' opinions with an estimate of all the positive qualities of a straight wing by considering such factors as the technological effectiveness and labor intensiveness for manufacturing wings in mass production.

In developing this aircraft, many fundamentally new design and engineering solutions were employed, solutions which promoted mass production and operational simplicity. The production line method of wing assembly, which was used for the first time when the IL-20's were built, completely justified itself and was used in industry for many years. A method of basing wing assembly on the skin and not on the framework, cutting the wing cord-wise and the widespread introduction of press-riveting in the fuselage which was divided into production panels--these were the primary, rational features of Il'yushin's method which was the basis of aircraft mass production.

The record-breaking, exceptionally low cost of the IL-28 in series production was a direct result of S. V. Il'yushin's ability to organize joint creative work with the plant.

During the design of the IL-28, the concept of invulnerability, which was developed when the IL-2 and IL-4 were built, was realized. The new bomber had two gun mounts to cover the forward hemisphere and a powerful gun turret to defend the aircraft against fighter attacks in the rear hemisphere. The crew and gunner had reliable armor protection.

The IL-28 was built in bomber, torpedo bomber, reconnaissance and trainer versions at several plants. Just like its predecessors, aircraft production reached the thousands.

It is customary, when writing about a designer, to talk about the aircraft he built. However, several words should also be said about the aircraft which were designed but not built. We should dwell on this since, otherwise, it is not possible to gain a complete understanding of S. V. Il'yushin and his credo as a designer, citizen and man. S. V. Il'yushin was assigned the mission of building a supersonic bomber on several occasions. S. V. Il'yushin exerted a lot of effort to accomplish this mission but, when he became convinced that the state of the art at that time did not make it possible to build such an aircraft, he dropped this proposal. The tests which were conducted showed that the designer was right. His awareness of the high degree of responsibility for the job assigned to him did not make it possible for him to direct the group's efforts at something which would not lead to the accomplishment of the assigned mission. High standards and objectivity in all issues were the distinguishing features of S. V. Il'yushin.

Airliners were the third creative area in Designer-General S. V. Il'yushin's work. The Experimental Design Bureau group began planning their first airliner in 1943 while battles were still in progress at the front lines.

Before the war, the majority of the passengers were transported on the twin-engine, 20-seat, domestically produced IL-2 aircraft; it was built on the basis of the DC-3 airliner which is still being used in some countries due to its outstanding features.

Il'yushin's first airliner, the IL-12, arrived on Aeroflot air routes in 1946. It was designed for 27-32 passenger seats. Its range was 2000 km. Its performance met world standards and it had greater economy than its predecessors--the widely popular American DC-3 and the domestic IL-2.

In concept, the IL-12 would not only carry passengers but it would also transport the most diverse types of cargo. Since it was not profitable to combine the two versions--a passenger and cargo aircraft--into a single aircraft, the design bureau developed a special version, the IL-12D with a reinforced floor and a large door on the port side of the fuselage, which supported transporting cargo weighing up to 3000 kg. At that time, airlifting this amount of cargo was a great achievement.

The IL-14, which was built in 1953, was a significant step forward. The group was assigned the mission of ensuring a higher degree of reliability and better passenger comfort and of increasing the all-weather capability and operational efficiency. For this purpose, the IL-14 (as compared to the IL-12) carried additional flight control and navigational equipment and electronic support equipment weighing over 500 kg.

One of the primary problems in developing this aircraft was ensuring take-off with a single engine failure. The specifications for designing the primary systems were subordinated to meeting this requirement. Thus, gear retraction time was reduced to 4-5 seconds. They had to spend a lot of time on the steering surfaces. But, the realization of all the designer's plans significantly improved flying safety and made the aircraft operationally reliable and comfortable.

The IL-14 was literally produced in versions "for any contingency." In addition to the airliners, cargo, military transport, "salon" (administrative) and agricultural aircraft were built. Special-purpose aircraft were built for aerial photography and all kinds geodetic and geographical work. Altogether, there were 14 versions of the layout of the IL-14's internal accommodations and each version had its corresponding special-purpose equipment. In flying performance, the IL-14 was simple to control and not demanding. It is not by accident that it was called the "workhorse." Today, many of Aeorflot's "customers," such as polar explorers, geologists, maritime and ice explorers,cannot imagine working without this aircraft.

The IL-14 is being used successfully in the Soviet Union and other countries. The CSSR and the GDR have been producing this aircraft for a number of years according to Soviet technical documentation.

The next aircraft--the IL-18--already belongs to the era of jet aviation. The designers were faced with the task of ensuring large-scale passenger transportation by reducing operating costs; i.e., of making air transport accessible to the broad masses of workers in our country. It was necessary to reduce the cost of a ticket on the IL-18 to a level equal to or close to the cost of a trip by sleeper-coach in order to attract passengers. This was Il'yushin's understanding of the problem.

Almost at the same time the IL-18 was planned (actually, somewhat earlier), the Vickers Company (England) began to design the Vanguard while, in the U.S., the Lockheed company had already built the Electra. At that time, the foreign press talked about the "competition" among the big three (the Electra, the IL-18 and the Vanguard). The IL-18 was designed, tested and built in a record-breaking short period of time.

All the IL-18's actual performance data and technical specifications confirmed the designed performance announced by the designer-general. This kind of fit is typical of Il'yushin's organization. The IL-18 was the first Soviet airliner which was in widespread demand on the world aircraft market. The aircraft was tested for compliance with ICAO* standards and it received an international certificate of air worthiness.

Based on orders from the USSR Ministry of Civil Aviation and 17 foreign airlines, several hundred IL-18's were manufactured. Over 100 aircraft are still being used today by many world airlines. The Vanguard and Electra mentioned above did not become very widespread, while the IL-18 was one of the most high-volume, first generation gas turbine aircraft. Based on its economic peformance, it occupies a worthy place among aircraft in this class.

The sale of the IL-18--including the preparation of the voluminous documentation, and the multi-faceted experience from their operational use by foreign airlines--had the foundation for a relatively new trend in our country's trade--the supply of airliners to the international market. The performance of aircraft designed by Il'yushin has always been at a high state of the art. However, it is well known that even good aircraft quickly become obsolescent. To ensure an extended life for them, it is necessary to up-date them on a systematic basis; this was a continuing concern of the director general and the entire design group. It was already mentioned that there were several modifications to the IL-12 and the IL-14. The same can be said for the IL-18. The aircraft's versions have the following designations: the IL-18A, the IL-18B, the IL-18V and the IL-18D. From modification to modification, the number of seats increased (from 75 to 110). In addition, on the IL-18D, the maximum non-stop range was significantly increased (by 30 percent), while the maximum pay-load range was increased by 35 percent.

All of this led to an increase in the operational efficiency and safety of passenger transportation. As a result, it can be said that the IL-18 has become a model for civil aviation in economic efficiency, handling simplicity and comfort. Moreover, this was achieved not only by trials during the initial and engineering design phase and during construction of prototypes but also during the aircraft's operational use and development via modifications.

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* ICAO - International Civil Aviation Organization.

Time passed and the task of increasing range and speed arose. S. V. Il'yushin had to come up with a new solution to this problem. The designer-general adopted the IL-62 for a new passenger aircraft; it was already among the second generation of jet airliners and was configured with a four-engine power plant in the tail section of the fuselage. This made it possible to get rid of the noise which tired out the passengers, especially on an extended flight. In addition, this location for the engines made it possible to obtain a "clean" wing with good aerodynamic efficiency and it made it possible to develop the most effective high-lift devices. Il'yushin used an aerodynamic wing configuration with an unusual "dog-tooth" leading edge. This made it possible to obtain outstanding longitudinal moment characteristics throughout the entire range of attack angles, including super-critical angles.

The designer-general understood that the engine location configuration which had been adopted not only had advantages which were very important for a long-endurance aircraft but it also had shortcomings: this location for the engines could increase the aircraft's empty weight by 6-7 percent. A lot of work and inventiveness were required for the job of partially eliminating this shortcoming. A successful solution was found in the form of a fundamentally new configuration for the gear with a retractable tail undercarriage. At the present time, the IL-62's four-point gear has been patented in a number of the world's leading industrial countries. This configuration made it possible to significantly reduce the structural weight penalty caused by locating the engines in the tail section of the fuselage.

The IL-62 made its first transcontinental flight in January, 1963. This aircraft comfortably accommodates 168 passengers. The non-stop range is 8,700-9,200 km at a cruising speed of 830-850 km/hr.

During its first days of operation, the IL-62 began flying on international routes. It is not easy to obtain permission for flights to the U.S. Before obtaining permission, there is an analysis of numerous data on the aircraft by specialists and there are flight tests, for example, to determine the level of noise created by the aircraft at the airport and in its environs. All of this was thoroughly and scrupulously accomplished by U.S. aircraft specialists. The result--certification for flights to America.

The aircraft's receiving the certification testifies to the fact that it meets international standards for civilian aircraft airworthiness. A number of airlines have bought this aircraft.

Several prominent airlines, like Air France, KLM, JAL and others, have leased IL-62's for use on their routes.

Years passed. Aeroflot was expanding its international contacts. Regular routes are being opened up to South America and Australia. Increased requirements, both in range and speed, were being levied on the aircraft serving these routes. The designer's creative thinking was directed at accomplishing these requirements.

On numerous occasions, Academician S. V. Il'yushin examined ways to solve the difficult problems mentioned above. With his direct participation, they studied different versions of the aircraft, including a version with a different wing. The studies showed that the most rational way of giving the IL-62 significantly increased range, without any serious, basic changes to the airframe and with minimal expenditures, was to use a power plant with better performance (and with a simultaneous increase in aircraft fuel capacity). For this purpose, the new D30KU turbo-fan engine designed by P. A. Solov'yev was selected; it has a take-off thrust of 11,000 kg/force, low fuel consumption and a new thrust reverser. In performance, it was as good as the world state of the art.

This engine has a by-pass ratio of 2.33 instead of the 1.0 ratio for the NK-8-4 engines, which are installed on the operational IL-62's. In spite of the noticeable improvement in the by-pass ratio and the greater diameter of the new engines resulting from it, they were able to accommodate them in the nacelles without any actual increase in their maximum cross-section (the nacelles' cross-section). At the same time, the aerodynamic shape of the nacelles was improved somewhat and this had a favorable effect on cruise conditions, especially at large Mach numbers.

Several other innovations were made to the aircraft design: the fuel capacity was increased by 5000 l (by placing an additional tank in the tail-fin); the shape of the stablizer fairing and the tail-fin was improved; the spoilers (high-lift devices) began to be used not just in the braking regime but also in the electronic regime; the design of the control yoke was changed; the instrument layout was made more convenient; a containerized baggage-loading system was introduced; and part of the navigation and radio communications equipment was replaced.

The clam-shell thrust reversers used on the engines were a significant improvement. This design is preferable to the cascade-type because there is no harmful aerodynamic drag and it actually does not increase engine fuel consumption.

Due to the IL-52M modification of the aircraft, the operational range was increased. With a maximum load of 23,000 kg, range increased from 6,950 to 8,270 km; with a pay-load of 10,000 kg (100 passengers), range increased from 8,700 to 10,000 km. This increase in range makes it possible to make trips to South America Australia and Africa without any difficulty. The cruising speed was also increased--from 850 to 870 km/hr.

Depending on the length of the route, the IL-62M can carry a pay-load 43-81 percent greater than the IL-62. For example, on a flight from Moscow to Tokyo, the IL-62M can take 18 tons on board while the IL-62 can only take 13 tons. The increase in pay-load combined with the high speed makes it possible to significantly increase the aircraft's operational economy.

It is well known that the results of any creative work and, consequently, the improvement of various aircraft, are recognized by a comparison. For this purpose and also to track the development of civil aviation, some diagrams were made (Figures 1-4); these diagrams illustrate the changes in the basic performance and parameters for similar passenger aircraft of two firms: S. V. Il'yushin's Experimental Design Bureau and the British Vickers Company. An examination of these graphs makes it possible to draw the following conclusions:

--during the developmental process, there is a continual increase in aircraft size (its tonnage), in passenger capacity, cargo capacity, speed and range, productivity and other statistics on its effectiveness as a means of air transport;

--aircraft development is uneven; discontinuities appear when new engines appear;

--the speeds for the aircraft of these firms are practically the same;

--during their respective periods of development, improvements to these aircraft were at the same state of the art.

Numerous Il'yushin military and passenger aircraft have been built. Aircraft with the IL trademark are serving hundreds of domestic and international routes; this vividly testifies to the good qualities of these aircraft.

The Il'yushin aircraft were some of the primary aircraft in the last war; they endured the severe test of combat and now they are carrying a large volume of passengers and are high-volume aircraft in the USSR Civil Air Fleet and in a number of foreign countries. During the 40-year history of the Il'yushin group's creative work, aircraft designed by it have continually been in large-scale series production, large-scale operational use and in the Soviet Air Force's inventory in large numbers.

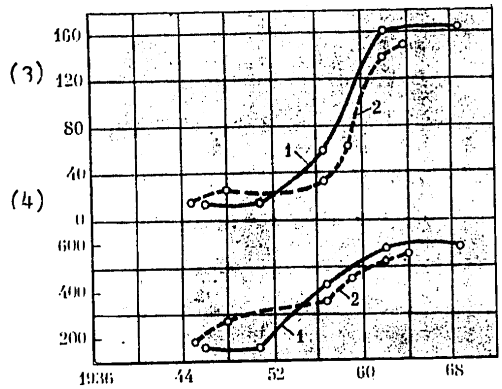

Figure 1. Increase in Take-off Weight and Gross Wing Loading During Passenger Aircraft Development.

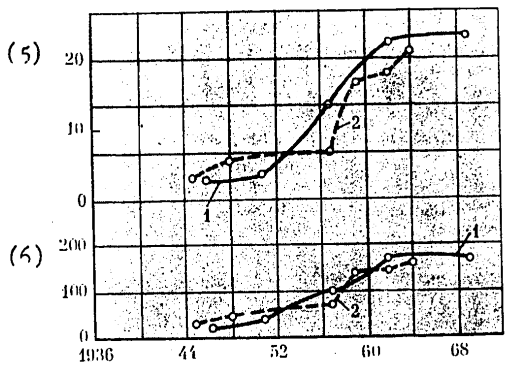

Figure 2. Dynamic Growth in maximum Payload and Number of Passengers During Passenger Aircraft Development.

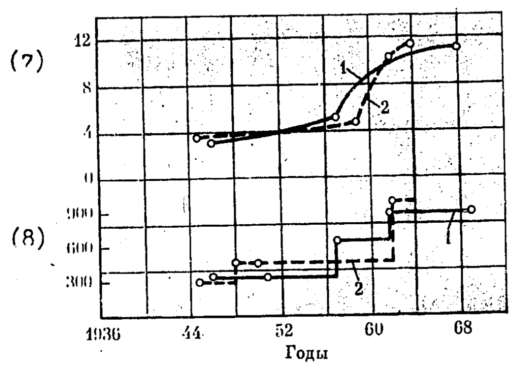

Figure 3. Increase in Maximum Range and Cruise Speed During Passenger Aircraft Development.

(11)

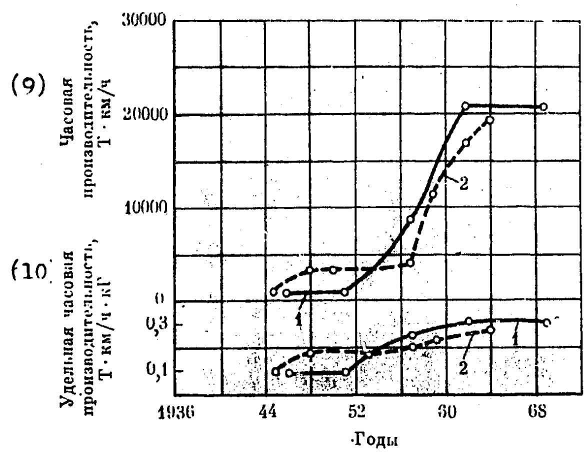

Figure 4. Productivity Growth During Passenger Aircraft Development.

(11)

Key:

1. S. V. Il'yushin's Experimental Design Bureau aircraft
2. Vickers Company aircraft
3. Take-off weight, tons
4. Gross wing loading, kg-force/m^2
5. Maximum payload weight, tons
6. Number of passengers
7. Maximum range, thousands of km
8. Cruise speed, km/hr
9. Hourly productivity, tons · km/hr
10. Gross hourly productivity, tons · km/hr · kg-force
11. Year

These facts eloquently prove that Sergey Vladimirovich Il'yushin's role in the development of domestic aviation has been invaluable. This is the reason Academician V. V. Struminskiy wrote: "When we talk about aircraft designed by S. V. Il'yushin, an entire string of outstanding, technically efficient aircraft come to mind; each of these aircraft is a page in the history of Soviet aviation."*

*KOMSOMOL'SKAYA PRAVDA, 12 March 1970.

CHAPTER 3

SOME SPECIAL FEATURES OF S. V. IL'YUSHIN'S CREATIVE WORK

Academician A. I. Makarevskiy, Hero of Socialist Labor
and Lenin and State Prize Winner

Technological progress in the 20th Century, especially in the first half of it, has been characterized by the establishment and development of aviation. It was aviation which required the development of many areas of applied mechanics and the creation of the other engineering disciplines which provided a fundamental scientific basis for its progress. The engineering disciplines provide the principles for solving individual problems in aircraft development. The concrete realization of scientific achievements in developing a specific design to meet multi-faceted requirements, requirements which are contradictory in a number of cases, is left to the designer.

There is a requirement for a great deal of erudition and experience, engineering ingenuity and intuition in order to combine these requirements and the achievements in science and technology into an effective design decision. This is why the designer-general's role (or the chief designer's role) is so great in aviation.

He is the one with the key idea for developing a particular aircraft with its special features and new qualities which have not been realized before. Following this key idea, the designer-general resolves all the contradictions which arise in the design and, by combining the efforts of his own design bureau and the associated organizations participating in the development of a particular aircraft, he achieves the optimum solution. The creative process requires special qualities of the designer-general, not only in the area of his scientific and technological erudition but also as the manager of the creative work of a large group.

Our country knows the names of many designer-generals in aviation, designer-generals who have written glorious pages in the history of aircraft development. Among these names, the name of Sergey Vladimirovich Il'yushin is especially significant. It is not possible to provide a complete description of Il'yushin's work in a single, limited article. Therefore, I will only attempt to point out some special features of his creative work as they appeared to me as a result of the extended business association between the Central Institute of Aerohydrodynamics and S.V. Il'yushin's Experimental Design Bureau.

The judgements expressed by S. V. Il'yushin on scientific and technological issues were typically concrete and descriptive in nature. These traits, which are generally inherent in talented designers, were always supported by Il'yushin with an evaluation of the possible alternatives for engineering solutions; this established his scientific and technological erudition and enormous experience. It was difficult to argue with him since he demanded a great deal of consideration and specificity in the opinion of his conversationalist's judgement on the issue being examined. If his talking partner's conclusions were convincing and Sergey Vladimirovich accepted his proposal, then he could rest assured that it would be implemented in the best possible manner.

The development of a modern aircraft is an extremely complex, creative process; a large number of people and organizations participate in this process. The trade-offs which naturally arise between individual requirements and the technical means to accomplish them have to be surmounted. This is where the designer-general's, or chief designer's role, is especially important. S. V. Il'yushin was able to subordinate all the individual echelons in research and testing, design and production to a single goal--obtaining the required operational performance for the item being developed. This is the primary meaning of an optimum solution and Il'yushin was able to find it.

When developing a design, he never forgot about the issues of providing for the comfort and safety of the people located on the aircraft. This concern was always manifested--during the design of both civilian and military aircraft. A characteristic feature of Il'yushin's creative work is the simplicity of his design solutions. In his memoirs, A. S. Yakovlev takes special note of this trait, calling Il'yushin "the master of simple solutions." Of course this "simplicity" required enormous creative effort and a completely accurate and clear idea of the operational use for the aircraft being designed. We find the embodiment of the designer-general's creative features in each aircraft developed by the design bureau under S. V. Il'yushin's leadership.

One of the important indices of progress in aircraft is maximum speed in level flight. The successive prototypes of military aircraft under development had increasingly higher maximum speeds. It was necessary to possess a great gift of foresight in order to propose an aircraft in the 30's with a moderate speed but with new tactical capabilities to make up for it--the IL-2 ground attack aircraft. The designer's confidence was governed by his well-thoughtout position on the aircraft's purpose and the conditions for its operational use. There was no requirement for a high-speed aircraft to wage combat with maneuverable ground-based targets but there was a requirement for a high degree of protection for vitally important parts of the aircraft, including the crew, against damage during low altitude flight.

The IL-2 developed under Il'yushin's leadership had powerful armament and good armor protection.

The development of a ground attack aircraft was a difficult and complex task which required a solution for a number of problems and a special approach to theoretical research efforts. This applied primarily to determining the performance required for the armor material and developing material which would meet this performance. With the assistance of the appropriate scientific research organizations, the armor was developed within a relatively short period of time; this, in itself, was a contribution to aircraft materials science. New engineering problems were solved for the air frame configuration: especially vulnerable spots requiring armor protection were established; the armor was integrated into the load-carrying structure and the necessary strength and rigidity of the latter were ensured by using various kinds of materials in it. The powerful armament and armor made the aircraft heavier. Consequently, a thorough structural engineering analysis was required. Moreover, it was necessary to take into account the fact that the aircraft had to be mass produced to meet its purpose and its manufacture had to be as simple and cheap as possible.

World aircraft production had not seen an example of the development of this kind of aircraft, although attempts had been made in this direction. The design group under Sergey Vladimirovich's leadership was able to solve this complex engineering problem. The development of the IL-2 was not only a brilliant engineering solution but it also opened a new page in the operational employment of aircraft.

During the Great Patriotic War, primary attention was naturally devoted to the production of military aircraft; but, even in those years, the development of transports and airliners was being examined; our country began building these aircraft after the end of the war.

The design of airliners took up a relatively large percentage of Il'yushin's work. Special requirements are levied on airliners. The primary requirements are profitability, operational reliability and comfort. The IL-12, the IL-14, the IL-18 and the IL-62 meet the world state of the art for airliners in their class and completely satisfy the requirements listed above. There is nothing surprising in the fact that it was Il'yushin who was able to resolve the very difficult problem of developing a reliable, profitable airliner. As already mentioned, the special feature of Sergey Vladimirovich's creative work was his in-depth understanding of the role for the aircraft being developed and his ability to subordinate all the individual design solutions to this purpose. This ability was most vividly and effectively displayed during the development of airliners.

The IL-12 and IL-14 were the first mass-produced, domestic airliners. These aircraft were in series production for ten years and they were the ones that supported the development of air transportation in our country when this type of transportation was beginning to be used in the national economy.

In 1959, the IL-18 heavy turbo-prop airliner began its service on Civil Air Fleet routes; it still does a large volume of transportation today. The development of an airliner designed to carry over 100 people several thousand kilometers at an altitude of 8,000 m and a speed of 700 km/hr was a difficult task requiring solutions to many new problems. The numerical increase in the technical specifications and performance of the IL-18 as compared to those for the IL-14 introduced significant qualitative difficulties in realizing them.

Let's cite just one example. To ensure normal conditions within the passenger cabin, it was necessary to develop a pressurized fuselage with the required pressure within a rather large cabin. For this purpose, it was necessary to guarantee the strength and fatigue life of such a fuselage at a low weight. After all, with its enormous dimensions, the fuselage had numerous cut-outs for windows, doors and hatches; these were additional points for possible fatigue failure. A very thorough structural analysis and a large number of tests were required to ensure the necessary airframe fatigue life.

In conjunction with CAHI, S. V. Il'yushin's Experimental Design Bureau conducted a large series of laboratory tests on strength and fatigue life, including a full-size aircraft, simulated iterations of the load spectrum and a similar simulated spectrum in operational use. These tests made it possible to detect points of possible fatigue failure and to ensure the airframe strength throughout the aircraft's operational life. The British Civil Fleet paid for the British specialists' failure to properly evaluate these features for structurally ensuring the fatigue life of its first jet airliner, the Comet, with a number of serious catastrophies.

The IL-62 intercontinental airliner began operations in the second half of the 60's. It had a suitable combination of earning capacity, reliability and comfort. A great deal of research and design work was required to achieve this combination. Locating the engines on a special pilon in the tail section of the fuselage had certain positive aspects, although, at the same time, it complicated the problem of weight efficiency. Comfort was significantly enhanced: no vibration or noise from the engines was felt in the cabin while airborne. The aircraft wing design had a significant effect on its aerodynamic performance and it made it possible to make more widespread employment of take-off and landing lift devices. But, naturally, all of this made the airframe heavier and a great deal of effort was required from the entire design group to ensure that the aircraft's economic efficiency did not suffer with the increased weight.

Everything in this aircraft was subordinated to its role and, from this point of view, it is the most optimum aircraft in this class of foreign intercontinental airliners. Once, at Sheremet'yevo Airport, we met a delegation of French aircraft specialists who had arrived for the Symposium on Civil Aircraft Fatigue Life Problems. The delegation flew in on an IL-62 and, in response to our question on how they were, we heard enthusiastic comments about the aircraft. All the delegation members pointed out its high degree of comfort, which met the world standard, and, we felt they had been looking over the aircraft closely and critically while airborne. The aircraft was subsequently shown at international events on numerous occasions and received high marks.

The desire of S. V. Il'yushin's Experimental Design Bureau to up-date aircraft in series production and to achieve a truly complete utilization of the performance built into aircraft created by them is extremely important; this makes it possible to keep the aircraft in operational use for an extended period of time.

Meetings with Sergey Vladimirovich always left you with a feeling of satisfaction and accomplishment. His inherent straightforwardness, thorough consideration of the issue and true desire to consider all useful suggestions were felt during the discussion.

S. V. Il'yushin's creative style and are characteristic of a large number of the Experimental Design Bureau's leading researchers who worked under his leadership; this makes it possible to talk about the development of Il'yushin's remarkable school of aircraft production.

CHAPTER 4

THE AERODYNAMIC EFFICIENCY OF S. V. IL'YUSHIN'S AIRCRAFT

All of Sergey Vladimirovich Il'yushin's aircraft have possessed unusually high reliability and flight safety during their large scale use on the air routes of the Soviet Union and many countries of the world.

These qualities were achieved by an exceptionally successful selection of the overall aircraft configuration combined with superior aerodynamic efficiency and an effective solution to the basic design problems.

The superior aerodynamic efficiency of an aircraft is naturally determined by a whole package of factors and requirements which have continually changed over time and, specifically, with the increase in flight envelopes. Sergey Vladimirovich always paid an exceptional amount of attention to the problems of an aircraft's aerodynamic configuration and he participated in many of the studies and discussions conducted by scientists from the Central Institute of Aerohydrodynamics imeni Zhukovskiy [CAHI].

In the prewar years, the problem of the aerodynamic efficiency of high-speed aircraft flying at near-stall angles of attack in the maneuvering, take-off and landing regimes became especially critical due to the intensive growth in flight envelopes. At near-stall angles of attack, the boundary layer separates from the upper surface of the wing. This leads to a sharp reduction in lift, an increase in drag and, as a rule, to significant changes in stability and controllability. The problem of an aircraft's aerodynamic efficiency in general and of its aerodynamic efficiency in these critical flight regimes became especially important. The attention of leading scientists and director-generals was concentrated on solving this problem.

Sergey Vladimirovich Il'yushin directly participated in the practical solution to this problem while developing the first domestic high-speed aircraft, the IL-12.

At that time, there was no uniform point of view on these problems among CAHI scientists; in the final analysis, these problems determined aircraft survivability, maneuverability, operational reliability and flight safety. To a significant extent, these aircraft properties depend upon the special features which cause the boundary layer separation from the aircraft surface and the nature of this separation's development. Within CAHI, there were several different opinions on possible aerodynamic configurations for wings, configurations which could provide these most important aircraft qualities. The problem required a sufficiently strict theoretical basis and a clear physical explanation. In addition, there was a requirement to test the solutions in wind tunnels and during flight, i.e., under natural aircraft operational conditions.

At that time, A. B. Risberg was in charge of one of the important projects in developing aerodynamic wing configurations. He was an extremely erudite and qualified aerodynamics engineer with a good theoretical knowledge, specifically, on the theory of finite wing span; he developed new, more effective methods for estimating circulation along the wingspan. He supported his positions with sufficiently well-justified calculations and arguments and, thereby, advantageously distinguished himself from his opponents. A. B. Risbert was working on an aerodynamic wing configuration which would have precluded the possibility of slow separation on the wing tips during basic aircraft maneuvers. This could have been achieved by the proper selection of general geometric parameters for the wing: low-tapering (approximately 1.5-2), a small negative sweep and a special wing structure with a high lift capability on the wing tips and low lift capability at the wing roots.

G. F. Glyass developed another project in analyzing aerodynamic wing configurations. In his opinion, the configuration had to ensure an early boundary separation at the wing tips and thereby prevent the possibility of linear flow separations. In this case, high tapering (approximately 4-5) and positive sweep angles could be used on the wings, while sections with early boundary layer separation and, consequently, with extremely low-lift characteristics, could be used on the wing tips.

There were also other points of view on aerodynamic wing configurations, specifically, those according to which a high degree of tapering should not be used on the wings, positive sweep angles should be avoided and wings should be made of a single series of sections. Since, with a decrease in the relative thickness of the airfoil, there is usually an increase in its maximum lift within a 15-9 percent variation in the relative thickness of the wing chord, higher lift characteristics and a certain reserve of lift at the wing tips are automatically ensured under the conditions cited above.

From the foregoing, it is obvious that it was primarily necessary to learn to estimate the wing's maximum lift force, the critical angles of attack and the nature of the development of separation areas on the upper surface of the wing with sufficient reliability to evaluate the aerodynamic efficiency of wings at critical angles of attack and to establish the aerodynamic wing configuration.

For this reason, CAHI began to conduct intensive theoretical and experimental research on wing aerodynamics at critical angles of attack. Based on Prandtl's theory of the wing, a theory for calculating maximum wing lift at critical angles of attack and the distribution of separation areas along the wingspan was developed and validated. This work was significantly refined by the American methods developed by Anderson to calculate the maximum lift ratio. They made it possible to take a sound approach to the selection of geometric wing parameters (taper and length) and of air foil structures which ensured the necessary margin of lift at the wing tips and an attached airflow around them during the primary flight regimes. At that time, it was clear that, although extremely large margins of lift at the wing tips had a favorable effect on flight safety and reliability in critical regimes, they were achieved at too great a cost, specifically, by significantly increasing the weight of the wing structure and also by reducing the aircraft's lift characteristics during take-off, landing and maneuvering regimes.

To determine the required margin of lift at the wing tips and to test the validity of the various points of view cited above on the aerodynamic wing configuration, an entire series of finite wing spans were tested in a full-size wind tunnel at the CAHI at high-Reynolds numbers according to the various points of view and methods. These tests specifically showed that wings configured according to G. F. Glyass's principle performed favorably at large angles of attack but, as a result of the premature tip stalls, they had poor lift characteristics and low take-off and landing performance.

The wings configured according to A. B. Risberg's method also performed extremely satisfactorily in the near-stall regimes. However, the large margins of lift at the wing tips which occurred due to the premature wing root stalls also reduced the wing's lift and degraded the aircraft's take-off and landing performance. In addition, these wings were a failure weightwise.

The studies in the full-size wind tunnel also showed that the wings built from a single series of sections with a 15-9 percent variation in the relative thickness of the wing chord had a certain margin of lift at the wing tips in a number of cases but these margins were clearly insufficient. They frequently caused linear, non-symetrical boundary layer separations which would, as a rule, lead to an avoidable wing stall in flight.

The mathmatical studies and the tests made it possible to determine the required margins of lift at the wing tips which would ensure the necessary performance in reliability and safety during all possible aircraft maneuvers. It is completely obvious that these margins should be different for aircraft with different roles.

It looked like one of the most difficult problems worked on by CAHI scientists for a number of years had been solved. This was confirmed by the theoretical calculations and by the clear physical explanation as well as by the tunnel tests at full-scale Reynolds numbers. Then, when the ferver began to die down and the CAHI scientists had arrived at a single solution, some military and civilian pilots stated that all these fine experiments and complex mathmatical studies did not have any direct relationship to the problem since they did not match current operational flying experience.

The fact of the matter was that the LI-2 (Douglas DC-3) was in widespread use at that time in our country and a number of other countries. This aircraft's wing had a large taper (approximately 5) and a straight sweep at an angle of approximately +16 degrees. The wing was made up of a single series of sections. Based on the CAHI studies described above, it was clear that an aircraft with this kind of wing flying at high near-stall angles of attack should have a vividly pronounced tendency for wing stalling and for going into a spin. However, civil aviation pilots, as well as several military pilots, stated that they had never seen this kind of performance by an LI-2 at near-stall angles of attack. This statement was a surprise. Many years of theoretical and experimental studies became doubtful: either a serious mistake had been made somewhere in the CAHI studies or the statement by this extremely authoritative group of pilots was not valid.

At that time, it was well known that the LI-2 was used on a widespread basis in some of our air units and it was sometimes used under unusually difficult conditions there. The decision was made to send CAHI officials TDY to operational units. The meetings with a large number of highly skilled pilots who had to accomplish their combat missions in these aircraft provided a lot of valuable information. Specifically, it became completely obvious that no stalling was detected when the aircraft were used at low wing loadings (approximaely 150 kg/m^2). As a rule, the aircraft were flying at angles of attack significantly far removed from critical angles. However, under conditions which were more complex (flying at low speed with a high wing loading) and which approximated critical regimes, a sharply pronounced tendency toward wing stalling was observed in the LI-2.

When accomplishing complex combat operations, an overload version of the LI-2 was used and it flew at extremely slow speeds. The pilot stated that even the most capable pilots experienced a great deal of difficulty under these conditions. After the materials from the Long Range Aviation units were reviewed at the CAHI, the aerodynamic wing configuration with the sectional structure and attached flow at the wing tips received final recognition and was widely used to develop recommendations on the configuration of high-speed wings for aircraft with various roles.

The experimental series of wings finally validated the institute's recommendations; designer-generals S. V. Il'yushin, A. S. Yakovlev, P. O. Sukhoy and V. M. Myasishchev agreed with these recommendations.

Sergey Vladimirovich Il'yushin played a special role in the developmental history of domestic aviation. He was the first to build an aircraft which used the new aerodynamic wing configurations and which employed CAHI's new high-speed airfoils. This was accomplished on the IL-12 and IL-14 airliners which have been successfully used over a period of 30 years now on many of the Soviet Union's routes and abroad.

All of Sergey Vladimirovich's scientific and practical acitivties were characterized by unusually high standards for himself and by a sense of superior responsibility to the people. These are not just specious words; this is actually how it was! As is well known, the postwar years were characterized by an unusually high rate of development in aircraft equipment:

flight envelopes were quickly increasing; jet engines and swept wings were appearing. By the end of the 40's, the sound barrier had been broken and aviation had arrived at supersonic speeds. In the beginning, this leap forward in flight envelopes was accomplished in light fighter aviation aircraft. Then, the flight envelopes for bomber aviation aircraft began to increase. In the beginning of the 50's, the maximum speed of long-range, heavy aircraft was beginning to approach the speed of sound and ceilings had increased significantly. This leap forward in the development of military aviation could not help but have an effect on the upgrading of civil aviation.

Jet aircraft began to appear in the Civil Air Fleet. As is well known, the first domestic jet airliner was the TU-104 designed by A. N. Tupolev. The experience gained by Tupolev's design bureau in building a long-range, heavy military aircraft was used in the development of this aircraft.

S. V. Il'yushin was firmly convinced that the set of requirements which determined the effectiveness of an airliner had to be completely different and incompatible with the set of requirements for military aircraft. Therefore, Il'yushin in due time submitted a design for building the IL-18 airliner. This aircraft was inferior to the TU-104 in flight speed and ceiling. Therefore, his proposal was not adopted at that time. However, Il'yushin continued to stand fast on his proposal. A special commission chaired by the author was set up. An objective and detailed review of the concrete materials convinced everybody that Il'yushin was right. The commission gave the IL-18 the go-ahead. Many years later, I participated in a commission's work to evaluate the economic efficiency of domestic airliners. The commission stated that the IL-18 had the highest economic performance.

The IL-62 airliner is perhaps the designer-general's most outstanding creation. There is a great deal which is new and original in the aircraft, not only in its overall configuration and in the solution to aerodynamic and design problems but also in the details which frequently determine the fate of an aircraft.

Let's dwell on the main features of its configuration. The aircraft has a swept wing and a high horizontal tail unit; the engines are located in the tail section of the fuselage. It would seem that these are completely independent issues in the aircraft's aerodynamic configuration. Actually, they are very closely related. The aircraft was built approximately ten years after the first swept-wing fighters appeared--the famous MIG's and YAK's. The IL-62 was the embodiment of the collective experience gained by domestic and foreign aviation.

I will never forget what happened to one of the swept-wing fighters approximately 5-6 years before the IL-62 was built. The fighter was undergoing plant tests at large G-loads and at an altitude of 7-8 km. Suddenly, it went into a wing-stall, went into a spin, recovered from it and stalled again. According to the pilot's story, the ground was rushing up and he could not put the aircraft into level flight. Right at the ground itself, due to his exceptional courage and self-control, he was able to bring the aircraft out of the dive and land it. When they helped the pilot out of the aircraft, according to the testimony of eye witnesses, he could not walk.

We investigated what had happened for a long time; we analyzed the test proceedings and the recordings from the flight recorder. Repeat tests of an aircraft model were conducted several times and, finally, we understood that the cause was the incorrect selection of the horizontal tail section location.

In many cases, for wings with a sweep angle of 35 degrees and more, either a low-horizontal tail section or a very high one is the best. A high location was the only one possible for the IL-62. This also made it possible to find an optimal location for the engine nacelles, a location which ensured a significant reduction in the level of noise in the passenger cabin. Thus, the overall aircraft configuration was immediately "flushed out."

However, an enormous amount of work was required to actually complete this configuration. How many different wing, tail unit and engine nacelle shapes and relative positions for them were reviewed and tested in wind tunnels, estimated and analyzed as finals and studied during static and dynamic tests. Suffice it to say that just to develop the "dog-tooth" leading edge, which is similar to the widely used partitions designed to preserve the margin of lift at the wing tips, took hundreds of hours of tests in wind tunnels. As a result of the large amount of effort from S. V. Il'yushin's Experimental Design Bureau and the CAHI, this difficult task was handled successfully.

Sergey Vladimirovich Il'yushin's activities as a designer-general were characterized by an in-depth understanding of the heart of the processes, by firmness and persistence in over-coming the difficulties which arose and also by the closest possible contact with the scientists, engineers and technicians working at the forward frontiers of science. All of this taken together ensured a high degree of aerodynamic efficiency for S. V. Il'yushin's aircraft.

CHAPTER 5

ENGINEERING COMMITTEE CHAIRMAN

Designer-General O. K. Antonov, Academician of the Ukrainian SSR Academy of Sciences, Hero of Socialist Labor and Lenin and State Prize Winner

It is difficult to imagine a glider meet at Klement'yeva Hill* without the Engineering Committee headed by its devoted chairman, Sergey Vladimirovich Il'yushin.

I first had the occasion to meet Sergey Vladimirovich in 1942 and then later, now as a member and secretary of the Engineering Committee, I participated in several of the meets which were held under his leadership.

The Engineering Committee's work at meets was unusually complex. While there were nine gliders at the first national trials in 1923, there were already 48 of them at the second trials in 1924! Each year, more and more new designs were being built. Gliders were transported from all corners of the Soviet Union. At times, a dozen new gliders, and sometimes more, would appear during the day. The glider designers, builders and pilots were afire with impatience to begin flying as soon as possible.

The Engineering Committee had to study this large number of designs which, as a rule, were completely original, often unprecedented shapes and frequently built by people who were trying their hand for the first time.

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*In 1924, P. N. Klement'yev, a student at the Air Force Academy imeni N. Ye. Zhukovskiy, died during the glider contests in the Crimea. In his memory, the hill where the gliders took off was called Klement'yeva Hill. (Editor's note.)

It was necessary to have vast erudition, infallible intuition and a fantastic capacity for work in order to successfully handle this task; it was necessary to be extremely well-disposed toward people--the creators of this still semi-primitive equipment, people who had spent so much time, effort and energy on it and who had a single thought: to fly, fly... The young designers always found true concern, support and good advice in Sergey Vladimirovich.

Due to his calm, firm and highly skilled leadership, the chairman of the Engineering Committee and his closest assistants accomplished an enormous amount of painstaking work within a short period of time. They gathered up the blueprints for all the gliders which had arrived. If there weren't any, they compiled them on the spot. They checked the estimates for airframe strength. Sometimes, they conducted improvised strength tests. They checked for the anticipated stability and controllability and the glider's ability to fly; they made recommendations for correcting weak spots in the airframe.

More and more new tasks, bordering on problems, faced the chairman of the Engineering Committee. How could V. I. Cheranovskiy's tailless parabola be put into the air without wind tunnel tests? How would a wing with just a bottom brace act? How could the Tandem, the Triangle, a sail-glider and a seaglider be put into the air?

There was feverish activity in the tent where the gliders were located. These were not temporary hangars but rather workshops where people sawed, built, glued, machined, patched, helped each other, discussed and sometimes argued until they were hoarse.

And, all the difficult cases were brought to the Engineering Committee, the highest authority for all the participants in the meet.

Sergey Vladimirovich gave the go-ahead for my training glider, the Standard, which was subsequently produced in thousands of copies under the designations US-3 and US-4 at a glider plant of the Society for Assistance to the Defense, Aviation and Chemical Industries; he also gave the go-ahead for the Upara training glider, the City of Lenin glider and many of my other gliders.

With gratitude and deep respect, I invariably recall Sergey Vladimirovich's concerned attitude, his businesslike, friendly criticism and his fatherly support, the support of a senior comrade and friend, which is so important to a beginning designer.

The golden era of the dawn of gliding in our country is firmly and forever linked with the name of the remarkable designer, leader, public figure and man, Sergey Vladimirovich Il'yushin.

CHAPTER 6

FROM TRAINING GLIDER TO AIRLINER

LtGen V. S. Pyshnov, Professor and Doctor of Engineering Sciences

/At the Air Force Academy./ The first important steps in aviation in our country were the establishment of the Central Institute of Aerohydrodynamics (CAHI) in 1918 and the opening of the Moscow Aviation Tekhnikum in 1919. The leading role in scientific and pedagogical activity belong to the outstanding scientist, Professor N. Ye. Zhukovskiy.

The actual construction of new aircraft was undertaken by engineers who already had some experience. Naturally, during the first years, they were forced to work with the old methods, with a minimum number of designs and with very limited opportunities for laboratory research. The methods for theoretical estimates were also limited: they did not take into account a number of important factors and this led to inaccuracies in the estimates of new aircraft flying performance and controllability. Of the new design bureaus, three were working the most energetically: the bureau headed by D. P. Grigorovich, who was well known for his previous work as a designer; the bureau headed by the experienced engineer N. N. Polikarpov; and the CHA [Commission for Heavy Aviation] group which was established by CAHI researchers and specialists who had practical experience building the Il'ya Muromets aircraft. There were also other small design bureaus which did not take up any new problems and limited themselves to modifications of existing designs and there were also groups with an inventive bent which did not have sufficient theoretical grounding.

Practical success was primarily achieved by the people who built aircraft which did not differ very much from the existing ones. This was still not very significant progress but it did help accumulate the appropriate experience. At first, the

APPROVED FOR RELEASE: 2007/02/08: CIA-RDP82-00850R000200040052-8

realization of new plans led to failure. This is what happened to N. N. Polikarpov's first fighter and the CHA group's aircraft. The development of aviation science and the improvement in laboratory and flight research subsequently made it possible to change over to new configurations more confidently.

Before the revolution, there were two aviation centers in Moscow. One of them was at Khodynskoye Field. There was a military aviation school there, the Duks Plant flying base and an aircraft fleet and warehouse where aircraft arriving from France and England were assembled and flight tested. The second center was at Lefortovo. N. Ye. Zhukovskiy's famous aerodynamic laboratory was located on the premises of the Moscow Higher Technical School. Not far from it, on Voznesenskaya Street (now Radio Street), a small building housed the Aviation Estimates and Testing Bureau where Zhukovskiy and his students worked. The Moscow Aviation Tekhnikum began operating in the facilities of the aerodynamic laboratory but then was moved to the building where the estimates and testing bureau was located and which now houses the N. Ye. Zhukovskiy Memorial Science Museum.

N. Ye. Zhukovskiy's first lecture, which was the beginning of lessons at the Moscow Aviation Tekhnikum, was given in mid-October, 1919.

At the beginning of 1920, the tekhnikum was given premises on Malyy Kozlovskiy Lane and, on 1 May 1920, the day of the All-Russian Voluntary Work Holiday, it was moved to new premises (a former trade school, with classrooms, a workshop, small apartments and utility buildings). This was enough for the young higher educational institution* during its first years. The CAHI gave them an aerodynamics laboratory for educational purposes; the materials testing laboratory and the engine laboratory had to be set up. In September 1920, the tekhnikum was reorganized as the Red Air Force Engineers Institute imeni Professor N. Ye. Zhukovskiy.

On 17 March 1921, N. Ye. Zhukovskiy passed away. This was a heavy loss: the man that V. I. Lenin called the "father of Russian aviation" had died. Moscow's entire scientific community turned out for Zhukovskiy's funeral; students from the institute carried an aircraft with Nikolay Yegorovich's casket on it from the MHTS [Moscow Higher Technical School imeni N. E. Bauman] to the Donskoy Monastery Cemetary.

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*The Statute on the Aviation Tekhnikum states that it is a higher educational institution established to train aviation engineers. This statute is in the archives of the N. Ye. Zhukovskiy Memorial Science Museum. (Editor's Note.)

This sorrowful event was sad but life went on. The CAHI was developing, the design bureaus were working and studies continued at the Red Air Force Engineers Institute imeni Professor N. Ye. Zhukovskiy. Autumn came and new students arrived at the institute. It was in this group that I saw Sergey Vladimirovich Il'yushin for the first time. He was of average build, thin and very agile; he had a confident demeanor. I felt that he was not new to aviation.

Since many of the students were on active military duty and detached to the institute, it was decided to change the institute into a higher military educational institution. On 9 September 1922, the institute was renamed the Air Force Academy imeni Professor N. Ye. Zhukovskiy.

The Red Air Force Engineering Institute adopted the subject system of teaching similar to the one which existed at the MHTS. Attendance at lectures was not mandatory but attendance was required at practical lessons. There were no examination sessions. When students were ready to pass a subject, they told the instructor and he set up a meeting. There were no grades; if anybody was not sufficiently prepared, it was simply suggested that he come back again. The procedures for passing subjects were arbitrary. An examination was even permitted when the course had just started. During the examination, the test was not conducted based on examination cards but for the entire course; moreover, the answers on theory preceeded the solution of standard problems. If any problem was not solved, the examination stopped.

The positive side of this system was the fact that intense work continued throughout the school year. Each student selected a test on a subject which seemed within his capabilities and put off the more difficult ones while, however, attending the appropriate lectures and practical lessons. This system developed your ability to work independently, discipline yourself and evaluate your own degree of readiness.

The drawback to the subject system was that, if the student put off taking the examinations, he could not catch up on what he had skipped by the end of the school year and he was in danger of repeating the year or being expelled. This system gave birth to the so-called eternal students. When the institute was changed to an academy, the subject system was replaced; mandatory attendance at lectures and examination sessions was introduced. All of this was natural for a military educational institution where discipline and a strict schedule are required. However, the change was not actually all that significant. The students were considered to be adults who were serious and not in need of supervision. The Military Scientific Society at the academy promoted the development of initiative in the students; it stimulated the students' scientific and design work.

/Glider construction./ The primary factor which was decisive in the development of aircraft was the improvement in engines. Manufacturing an aircraft (a wooden frame, thin material stretched over it, secured by metal braces and guy wires or cables) was a relatively easy job; but, the engine had to be bought abroad and it was expensive. This slowed down the development of domestic aircraft production. An engine was beyond the reach for beginning designers and they turned to unpowered aircraft--gliders.

After Lilienthal's successful flights at the end of the last century, glider construction expanded and gliding became very widespread. In 1909-1911, a large number of make-shift, balanced gliders costing about 20-30 rubles were built in Russia. These gliders were flown by N. B. Delone, A. N. Tupolev, B. I. Rossinskiy, P. N. Nesterov and others. The balanced gliders could stay in the air for 10-20 seconds. Controlling the gliders was not so much control as it was a gross correction of their incorrect attitudes. The successful development of powered aviation during 1912-1914 cooled down the interest in gliding; at the beginning of World War I, the pursuit of gliding stopped altogether.

The most important characteristic for a glider is its descent speed when gliding in still air. Naturally, it was necessary to have wings with a large wingspan to obtain a slow descent speed. The balanced gliders had a wingspan of 6-6.5 m, a weight of approximately 100 kg, a lift-to-drag ratio of about 4-4.5 and a descent speed of 2.2-2.5 m/sec. This descent speed is small for descending. However, for soaring flight, it was necessary for the speed of the ascending current to be greater than the descent speed; but, currents with speeds of 2 m/sec or more were rather rare.

The transition to wings with a wingspan of 12-15 m and a lift-to-drag ratio of 10-15 made it possible to obtain a descent speed less than 1 m/sec, i.e., a factor of 2.5 less. Low descent speed combined with good controllability led to progress in the development of gliding in subsequent years--soaring flight became a reality.

At the institute, glider construction began in the beginning of 1921. The author developed a glider design similar to the old balanced gliders but with an elevator and ailerons. However, during testing, it turned out that the elevator was not very effective and this glider did not fly any differently than the balanced gliders.

The most senior Russian test pilot, K. K. Artseulov, who had gained experience building fighters before World War I, built the A-5 glider in 1922; its configuration was reminiscent of the Moran monoplane. With its low structural weight, it had a wingspan of 13 m and very effective control elements. It was test-launched by towing it behind a motor vehicle and it demonstrated very good flying performance. In the summer of 1923, the Society of Friends of the Air Force decided to hold the First National Glider Trials on the slopes of the mountains near Feodosiya where there were numerous upward currents. Since Artseulov's glider was the only one ready by this time, the trials were postponed until November so several more gliders could be built by that time.

The members of the Soaring Flight Glider Club--primarily students at civilian higher educational institutions and academy students--began building gliders. S. N. Lyushin took the easiest path. He took the wings from a Vickers fighter, attached a tail to them with a truss and built a small cabin and gear. He had a rather heavy glider with a small wingspan and a low lift-to-drag ratio; its descent speed was approximately 2 m/sec. This glider did not fly. S. S. Krichevskiy's glider was also close to a conventional biplane but he did not finish building it. I. P. Tolstykh's two-seat glider was built like an aircraft and it had a descent speed of 1.3-1.4 m/sec. Due to its aft center of gravity, it had an accident during its first take off; it made short hops after it was repaired. My VDA-2 glider was also a biplane; however, it had very long, thick wings. Its descent speed was approximately 1.1 m/sec. It took off from the side of the hill easily but then it began to bank, turn and, after catching a wing tip on the ground, it suffered slight damage. The cause of the accident was an inadequate vertical tail section.

The most successful gliders in aerodynamic and design performance were Nevdachin's glider and Tikhonravov's VVA-1. They were cantilever monoplanes; Tikhonravov's glider had a triangular wing. The glider's fuselage had a clumsy shape and this made its lift-to-drag ratio worse. The glider completed a flight and, during the next take-off, it made an abrupt turn and the wing was damaged.

Nevdachin's glider was the best in design and production quality; however, during the flights, poor longitudinal stability, resulting from the aft center of gravity, and poor vertical tail section performance were discovered. Thus, due to its low descent speed and good controllability, Artseulov's glider knew no peers and this established its victory during the competitions.

S. V. Il'yushin's glider, the VDA-3 Mastyazhart, was different from the others. Sergey Vladimirovich was not trying to set any records. His goal was to build a glider which was easy to produce and fly. The frame was very simple and light; the aerodynamics were somewhat simplified; but, the gross wing loading was small enough--approximately 6.5 kg/m^2--that it was possible to develop a flying speed of 10 m/sec and a descent speed of 1.3 m/sec. At this flying speed and with a headwind of 6-7 m/sec, his assistants could tow it by running alongside the glider when there was a small incline in the terrain. This is exactly how they tested it. While flying it, pilot V. Denisov discovered poor longitudinal stability in the glider due to the aft center of gravity. After putting an additional load forward on the glider, the stability improved significantly.

As can be seen, almost all the gliders had a center of gravity too far to the rear and poor vertical tail section performance. The problem in selecting the center of gravity was obvious--the pilot sat between the wing's spars. Only after the pilot's seat was placed forward of the wing did the center of gravity shift forward.

Artseulov's glider also had an aft center of gravity but its good horizontal tail section performance softened this defect.

B. I. Cheranovskiy's glider was completely unconventional: a very thick, parabolic shaped flying wing. In the following years, Cheranovskiy was able to obtain satisfactory flying performance in gliders with a similar configuration; but, in 1923, the glider was not tested.

In spite of the fact that Artseulov's glider was the only one to carry out soaring flights, the results of the trials made a very deep impression and the interest in gliding increased sharply. The second competitions were held in Koktebel' in August-September 1924. Academy students did not enter 3 gliders as in 1923 but 15; these gliders were built in the school workshops and in the glider clubs. The performance of the gliders made at the academy was improved significantly but the search for shapes and designs continued.

Almost all of these gliders were allowed to fly off gentle slopes but only gliders with enhanced stability were allowed to fly from the steep slopes of the Uzun-Syrt Mountains since a previous disregard for the requirements of enhanced stability when flying over steep slopes led to a catastrophe in which Academician P. N. Klement'yev died in a glider he designed. The most successful was the Larionych, a glider designed by I. I. Artamonov, a sophomore at the academy.

S. V. Il'yushin entered three gliders in the competitions. Two of them were planned to be soaring gliders and the third was a development of the Mastyazhart and was designed for training purposes. Unfortunately, the soaring gliders were built within short deadlines by inexperienced workmen and they did not yield high results. The training glider was called the Workers School Student; it was rather simple in design but was a significant improvement over the Mastyazhart. To give it greater stability, the pilot's seat was moved forward and located in a streamlined cockpit. The glider was easy to fly, controlled well and flew at a low speed so that the instructor could run alongside the glider and give the cadet instructions. A large number of flights were made on this glider and a flight on the Workers' School Student was a sort of "christening" for many glider pilots. I also had the opportunity of trying my hand at flying this glider.

A characteristic feature of S. V. Il'yushin's creative work--a desire for simple design solutions and high operational efficiency--appeared even during the development of his first glider. This trait can be traced in Sergey Vladimirovich's subsequent activities. He soberly evaluated the task assigned to him, was not carried away by fashions and built aircraft which quickly went into widespread operational use.

The year 1925 was a very tense one for S. V. Il'yushin. The work on his graduation thesis left little time for other activities. However, Sergey Vladimirovich still designed and built the new AVF-21 Moscow glider which was designed to participate in international glider competitions (along with four other gliders). These competitions were held in August on Wasserkupfe Mountain in Germany. The terrain relief in this area was unique and complex. The German glider pilots had been training here for several years now; everything was new for the Soviet glider pilots but, nevertheless, they turned out to be very serious competitors. All the Soviet gliders demonstrated superior flying performance and in-flight reliability, including S. V. Il'yushin's glider, Moscow.

/From the academy to the design bureau./ Glider building declined after 1925. The reason for this is easy to explain. The people who began the development of gliding and achieved success in it graduated from the academy and left for new jobs with the Air Force or industry. Sergey Vladimirovich received an assignment to the Air Force Technological Committee. This organization was in charge of the experimental development of aircraft equipment and the first section, where S. V. Il'yushin was assigned as the chief, supervised aircraft subjects. Sergey Vladimirovich had to study closely not only domestic aircraft production but also the achievements of the leading countries, the ideas which were controlling the development of aircraft production at that time and the scientific research and experience in using aircraft. S. V. Il'yushin's job at the Technological Committee was the school which prepared him for his independent design work. The period 1926-1933 was a very important phase in the development of aviation; it was a time when the groundwork was being laid for major changes in aircraft performance, especially in speed, range and load-carrying capacity.

The time was right for a change from the cloth-covered wooden winged, plywood-fuselage "classical biplanes" and from the corrugated metallic skin winged monoplanes with the crudely shaped fuselages and open cockpits to smooth-skinned monoplanes with closed cockpits, retractable gear, variable-pitch metal propellers and a number of other improvements. All of this demanded a complete reconfiguration of aircraft and a different approach to selecting their basic parameters.

Each new aircraft is characterized by a state-of-the-art which was designed into it, especially, the level of engine efficiency.

First, it is necessary to combine a number of conflicting requirements. Second, it is necessary to use measures which have still not been completely developed since the time factor is very important. The designer frequently has to make decisions without waiting until everything is explained by scientific research and experiments. However, success in building a new aircraft does not just depend upon the designer's technological erudition, his courage and his belief in progress. It is necessary to make an intelligent selection of the qualitative parameters or, as they say, the aircraft's "size." The following terms are used: the aircraft is oversized or undersized.

An aircraft is built by a group. During the early stage of the development of aviation, the groups were very small and consisted of the designer-idea man, two or three of his assistants, a production engineer, assembly supervisors, draftsmen and production workers. Engine mechanics and a test pilot were required for testing. Subsequently, the design bureau began to grow quickly. It was necessary to segregate the estimates bureau, the graphic design bureau and the following departments: prototype, tests, production, production equipment, set-up and flight station. Later, special laboratories, research groups with different goals and much more began to appear.

In spite of all this, the role of the chief designer and his closest, trusted people was still very great and their creative and practical traits left a mark on the equipment being produced. The chief designer could initiate a new proposal and this would greatly facilitate its success. The chief deisgner makes all the basic decisions in coordinating requirements, selecting alternatives, etc. He makes the decisions when difficulties arise, when there are accidents and when suppliers violate their obligations. He is the one concerned about attracting good specialists in all areas and about the teamwork of the entire design bureau.

Certain typical professional principles can be isolated in aircraft designers. The most primitive type of designer, the type which was very widespread during the early stage of aviation development, was the imitator. There were a lot of imitators of the Wrights, Farman, Bleriot and others.* Elements of imitation were encountered later and are even encountered now, only now this phenomenon cannot be considered simple imitation. This is the natural employment of rational ideas and the extension of developmental trends worked out in world-wide engineering. When the supervisors of design bureaus are analyzing information, everything beneficial in a particular type of information can be used.

Of course, the common idea that an aircraft design can be copied from a photograph should be renounced. A unique "fashion" can be observed in equipment development but the somewhat limited thinking of those who blindly follow it can only be a negative factor here.

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* V. B. Shavrov. "Istoriya konstruktsiy samoletov v SSSR" (History of Aircraft Design in the USSR), Mashinostroyeniye, 1971

During the early stage of aviation development, when the theoretical groundwork was still poorly developed, we can isolate a trend which can be called "natural selection." Designers were trying to diversify aircraft configurations, hoping to come upon a successful solution. This was warranted when several aircraft could be designed, built and compared during a year. The story of Farman's aircraft is noteworthy in this respect. At first, the Farman-3 was cumbersome and complex: biplane wings, a biplane tail section set far to the rear, a forward elevator, an open cockpit, uncovered fuel and oil tanks and uncovered control linkage. Then the aircraft was updated: at first, the tail section of the aircraft was shortened and then the lower wings; the tailfin became monoplane; the forward elevator was eliminated; the pilot and tanks were covered with a cockpit; and the gear was simplified. From the Farman-3, they arrived at the Farman-30; but, there was nothing else to be improved now: it was necessary to make a fundamental change to the configuration; this was done.

Elements of spontaneous experimentation were typical of the stage of development from 1920-1925. While working for a short time at N. N. Polikarpov's design bureau and being well acquainted with his previous work, I was able to observe his excitement when waiting on test results of a new configuration; when he was told that a new configuration was interesting and advantageous, he simply shook his head mysteriously, letting it be known that nothing more could be said until the flight testing.

There is also a work style where the designer, as the supervisor, willingly agrees to all the customer's requirements. The result of this kind of work is rarely favorable. The customer may not have an appreciation of the extent to which all the requirements are compatible with the capabilities of realizing them and the designer-supervisor must convincingly justify this by relying on engineering estimates and analyses. The desire to satisfy the customer's requirements sometimes leads to a superfluous complication of the aircraft design. All progress is linked to complexity in aircraft configuration and production technology; however, this is justified if it is really effective. But, design complexity can be ineffective and can lead to complications in operational use and even to a reduction in flight safety.

The designer-supervisor can have an inherent inclination for innovation, an inclination to develop ideas which are perhaps still not clearly formulated. In this case, his designs will have a more or less pronounced experimental nature. Experience shows that many designers are not willing to experiment since a certain amount of failure is still possible even when no doubtful steps are being taken in a new design; and the probability of failure is significantly higher in an experimental design. In itself, the discovery of negative characteristics has a very positive impact. Nevertheless, every failure leads to a delay in producing the design and this may lead to the loss of an order for series production and the transfer of a series plant to another experimental design bureau. However, there have been a lot of instances in the history of aircraft production where a single person has attempted the untried and other design bureaus have courageously proceeded to use the innovation when it was successfully resolved. We can cite one example here where S. A. Lavochkin was the first person to decide to use swept wings on jet aircraft after the theoretical feasibility of using them had been established. The positive characteristics of these wings were proven during high-speed flights and they were suitable for low-speed flight. This was a signal for all the design bureaus to change to the construction of aircraft with this configuration.

There is another type of designer-supervisor whose creative work deserves extremely high marks. These are the designers who devote their primary attention to the aircraft's operational qualities which meet the conditions for its employment--military or civilian. They are concerned about the aircraft's effectiveness in employment, simplicity in maintaining it, simplicity in handling it and its survivability and safety. This requires a systematic combination of all flight characteristics. As a result, good aircraft are obtained although no claims are made for record-breaking achievements in individual flight characteristics. These aircraft, as a rule, remain in operational use for a long time. For example, the British Avro 504-K(U-1), Polikarpov's PO-2, Polikarpov's R-5, the American Douglas DC-3, its Soviet version the LI-2 and the majority of S. V. Il'yushin's aircraft.

We have cited some typical types of designers' creative work. However, in each designer, there is a combination of elements from several types; this combination makes up the individuality of each designer-manager.

/Developing combat aircraft./ S. V. Il'yushin began his design work on military aircraft in the mid-30's.

At that time, the light MB [medium bomber] designed by A. N. Tupolev was in service with the Air Force. This aircraft's bomb load was not very large and its fuselage was small. Understanding that the Air Force required an aircraft which significantly surpassed the MB in its basic flight performance and technical specifications, Il'yushin began to design one; the initial version of this aircraft was called the CDB-26. There were several modifications to this aircraft but the last modification--the IL-4--went down in the history of domestic military aviation.

Sergey Vladimirovich's talent appeared even stronger when he built the IL-2 ground attack aircraft. The size of this aircraft was selected based on an estimate for obtaining a large load-carrying capacity. The IL-2's maximum lift force was 13.5 tons; with a full take-off weight of 5.8 tons, this gave an initial G-load ratio of 2.3 which was achieved at an instrument speed of 250-280 km/hr. Moreover, its time for a sustained bank was approximately 23 sec, which was close to the time of a sustained bank for a fighter at that time. The ratio between the aircraft's unloaded weight and its maximum lift force was 0.31; this was slightly larger than the same ratio for an aircraft without armor.

All of this was a manifestation of S. V. Il'yushin's exceptional ability to efficiently layout an armored box and use it as the load-carrying structure. This result was not achieved by any other ground attack aircraft designer. The armored cockpit covered the crew, engine and radiator; however, there was a slight loss in air blowing through the radiator. The armored cockpit not only protected the pilot and gunner against bullets and shrapnel but it also saved their lives during forced landings on unfavorable terrain. The IL-2 is an outstanding model of aircraft production.

In 1944, S. V. Il'yushin's new ground attack aircraft, the IL-10, went into service. In size, it was somewhat smaller than the IL-2; this brought about an increase in its speed of more than 20 percent. However, this was not only achieved by reducing the size of the aircraft and increasing engine power but also by significantly improving its aerodynamics. The maximum lift force increased to approximately 15 tons while the G-load ratio at full take-off weight increased to 2.4.

While continuing his work to improve the design of ground attack aircraft, S. V. Il'yushin decided to eliminate the inadequate forward-downward view inherent in the IL-2 and IL-10 aircraft. Several designers had tried to achieve this by using two engines mounted on the wings. They actually obtained a good view but the aerodynamics and survivability were worse. The engine hit probability increased by a factor of two; as a result of the large lateral separation between the engines and the aircraft's center of gravity, its controllability deteriorated sharply.

Il'yushin took another path. In his new aircraft, the IL-20, he placed the pilot above the engine. But, by this time, the Air Force had begun the transition to jet engines; as a result of this, the forward-downward view problem was resolved rather easily.

During the changeover to turbo-jet engines, Il'yushin built the four-engine IL-22 bomber. During the test flights, several deficiencies were discovered in the aircraft, deficiencies which forced them to look for new solutions.

At the end of the 40's, along with the widespread research on the problem of breaking the sound barrier and using supersonic speeds, work was being conducted on building aircraft with transonic speeds. S. V. Il'yushin's Experimental Design Bureau developed the straight-wing IL-28 bomber. A lot of specialists protested against this design; however, the aircraft was built quickly and submitted for flight testing. By this time, the TU-14, a similar aircraft, was already undergoing testing. Preference was given to the IL-28. The IL-28's significant advantage was its lower structural weight and, consequently, its increased thrust-to-weight ratio. Its aerodynamic configuration was also more progressive.

S. V. Il'yushin also developed a heavier aircraft--the IL-46--and two swept wing aircraft with similar roles--the IL-30 and IL-54; but, the IL-54 was not introduced into the inventory for reasons not related to the aircraft's performance.

/Toward an intercontinental jet liner./ Air transport made its appearance at the beginning of the 20's. The first Junkers and Fokker aircraft used in the USSR were for four passengers. Later, domestic aircraft with increased load-carrying capacity designed by A. N. Tupolev, K. A. Kalinin, A. I. Putilov and other designers, were developed. A significant event was the acquisition of a license for the American Douglas DC-3, which was built in a passenger (PS-84) and cargo (LI-2) version. But, this aircraft had shortcomings: it was difficult to control when a single engine failed and its speed and load-carrying capacity were inadequate.

S. V. Il'yushin decided to make a replacement for the LI-2. At the beginning of 1946, the IL-12 was completed and in 1953 the IL-14 was finished.

The four-piston engine IL-18 airliner was built at almost the same time as the IL-12. This aircraft was able to compete with similar American aircraft which were already making scheduled trips across the Atlantic Ocean. However, the length of our Civil Air Fleet's routes was still not long enough at that time to use the IL-18 on them. Approximately ten years later, the IL-18 appeared with significantly greater tonnage and with turbo-prop engines which had enormous advantages over the piston engine. They were approximately twice as light, were smaller in size, a great deal more powerful and more economical; they did not require a great deal of power to cool them and, finally, they were a great deal more reliable with a longer engine life. The IL-18 had a maximum lift force of 125 tons while the IL-14 only had a force of 37 tons.

The turbo-jet engines in the beginning of the 50's also had good weight and power characteristics but their economic efficiency was lower than the turbo-props. For transport aircraft, the turbo-prop engines were very advantageous if high speeds were not required. It is now possible to assert that S. V. Il'yushin's selection was correct and that the new IL-18 version turned out to be exceptionally economical during long-distance flights. Approximately another ten years passed and airliner speed, range and cargo carrying capacity requirements had increased. The IL-62 and the N. D. Kuznetsov engine were remarkable technological achievements for S. V. Il'yushin and for the group supervised by him. This aircraft has a maximum lift force of 450-480 tons with a maximum take-off weight of 160 tons.

Almost 40 years have passed from the light glider with an in-flight weight of 100 kg to the intercontinental liner with an in-flight weight of 160 tons. S. V. Il'yushin designed, built and flight tested dozens of aircraft; many of them have been unsurpassed in flying performance, design simplicity, technology and reliability.

CHAPTER 7

"THE FLYING TANKS"

AF Marshall A. N. Yefimov, twice-honored Hero of the Soviet Union

There are some remarkable creations of man's intelligence which become such a natural part of life that they are apprehended by modern people as something completely obvious and not able to be anything else, neither in overall concept or in the slightest details. Perhaps it is only from a position of past history that it is possible to evaluate the true meaning and importance of such creations based on their merits. But, the creator does not have that history of the future which will later appear in the hands of the historian. A designer's creative feat is all the more remarkable then when he has been able to design into his aircraft precisely those characteristics which are required of it during the fierce time of war. This kind of feat is unthinkable without real talent.

The IL-2 is sometimes called a stroke of creative luck, a designer's god-send. Of course, there are such things in creative work. But, an entire series of god-sends and their exacting, specific conjunction in an aircraft's combat capabilities cannot be simple luck. Behind this conjunction are the experience of flying and engineering duties, the designer's profound thinking on military problems, years of intense work by the talented, creative group established by Sergey Vladimirovich Il'yushin. The IL-2 ground attack aircraft was not simply the next step in the development of engineering thought, it was an entire epoch in the history of Soviet military aviation.

The idea of ground attack aviation's participation in battle was born in our country during the Civil War. "...couldn't you have military scientists X, Y, Z...answer (quickly):

[redacted]

airplanes against cavalry?... Flying very low," wrote Vladimir Il'ich Lenin.* And, Red military pilots successfully operated against the enemy's cavalry in old captured aircraft which were called "revolutionaries"; even at that time, the future designer Sergey Il'yushin, a mechanic on the aircraft maintenance trains, was able to bring them back to life.

Although small, the first completely positive experience obtained during those years using the "revolutionaries" made it possible for the Soviet Headquarters to make the decision in 1926 to develop ground attack aviation. The idea of ground attack operations was realized with the development of the ground attack aircraft.

Many well-known Soviet and foreign aircraft designers attempted to build such an aircraft. But, the ground attack aircraft, the battlefield aircraft was beyond them. It is unlikely that anybody had a clear idea of what it should be like at that time.

The first really major engagement with the enemy in the skies of Spain reconfirmed the fact that the troops needed support aircraft. However, the R-5 and the SSS aircraft being used there were not suitable for these purposes.

The low-altitude ground attack tactics being used with heavy opposition from anti-aircraft weapons did not match the operational performance of these aircraft. They were not effective enough and the combat losses were too high. This threatened the very existence of the idea of ground attack operations; this idea had matured in the minds of military specialists a long time ago; they had a feeling for it but they were not able to precisely formulate tactical recommendations on employing the aircraft or the appropriate tactical requirements for them.

On the one hand, it was clear to the military specialists that they needed an aircraft which was able to effectively support troops on the battlefield under conditions of very fierce fire from the enemy. It would not only have to search out small targets, primarily tanks and artillery, and strike them from the air, but it would also have to be invulnerable. On the other hand, the practical experience from troop combat training, and especially the experience of employing ground attack aircraft, showed that these requirements had still not been successfully combined in a single aircraft.

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* V. I. Lenin. "Polnoye sobraniye sochineniy" (Complete Collected Works), vol 51, p 43.

Therefore, doubt naturally arose about whether the very idea of ground attack operations was correct and whether there was a requirement to build a ground attack aircraft. A uniform opinion on this issue did not exist before the war. There were people who proposed a reduction in and even the elimination of ground attack aviation. It was even more difficult for S. V. Il'yushin at that time. Instead of looking for ways to translate the requirements which were already developed into metal, he had to develop and formulate his idea based on an analysis of the combat missions and conditions for employing the aircraft and then steadfastly insist upon his plans.

Evidently, Sergey Vladimirovich had such a good idea of what his brainchild would encounter in the war that there did not seem to be even a slight detail which the designer had not anticipated. His idea consisted of building a "flying tank." This was the basis of his plan.

We, the front line pilots, did not immediately perceive the remarkable combat capabilities of the IL-2 ground attack aircraft. I made my first combat sortie in the IL-2 during an asault on trainloads of Hitler's soldiers at Osuga Station between Rzhev and Vyaz'ma. We were flying without a fighter escort. We crossed the front line at low altitude, arrived at the railroad and turned north. "Get ready, hunchbacks!" Lt Anatoliy Vasil'yev, the flight leader, commanded. We were endearingly called "hunchbacks" due to the slight rise in the aircraft canopy which made the ground attack aircraft look somewhat hunched. Our troops could easily identify the aircraft by its appearance; this was an important factor since we usually operated directly over the battlefield and could have been fired on by friendly forces.

The enemy, who had an aircraft warning service operating near the front, was also familiar with our aircraft's configuration. And, this time, while we were still approaching Osuga Station, Hitler's anti-aircraft batteries opened fire on us. Threads of fiery red "lines" stretched out to meet the ground attack aircraft. These were the tracers from Hitler's "elite" anti-aircraft guns which harassed us throughout the war.

The dull gray puffs of bursts, which gradually formed a thick shroud, arose above and below our flight path. The ground attack aircraft flew through this shroud as through a fog. It was as though the surface of the aircraft was covered by pock-marks; the surface was pierced by shell fragments. Some holes were large, the size of a fist, and others were smaller. But, in spite of the numerous fragment hits, the engine was working normally and the aircraft was still responding. The armor which completely covered the aircraft saved us.

With our first acquaintance, the aircraft made a big impression on us, the ground attack pilots, with its military appearance and sturdiness, a sort of monumental strength, it could be said. We especially liked the cockpit which was forged into the clear, steel armor. In it, you felt protected against all dangers during operations under enemy fire. This was especially important, as I understood later, not so much for the wingman as for the element leader. The wingman had to do what the leader did and follow him. The leader, who had to break through to the target and lead the entire formation to it, had to overcome a psychological barrier at a certain moment and exert a serious effort of willpower in order to swoop down, head-on into the fatal danger, through the dense shroud of anti-aircraft bursts which the enemy set up to force us out of the attack or at least to make it more difficult. But, it was not easy to force a pilot out of the attack. The IL-2 was well disposed to combat; it invited you to attack.

Of course, at that time, I did not know all of this and was only carrying out the duties of a new wingman. In the smoke from the powder, the leader was barely visible. A new trail from the "elite" guns again forced an anti-aircraft maneuver. Descending, I pulled out sharply to the side and clearly saw four anti-aircraft guns, the gun crew around them and the flame and smoke from firing. I fired a round, a second, a third. Through the side of the cockpit, I was able to see the Hitlerites running around: either I had a good hit or I scared the fascists, who decided that I wanted to ram the battery since I had brought the aircraft out of the dive very low.

When recovering from the attack, I again came under anti-aircraft fire. I remembered the saying which the senior pilots taught us, the newcomers: "If you see a burst close to you, fly into it. The next burst will not be there since it will hit another spot based on a previously selected correction for the aircraft's movement. If the burst was far away, go away from it since the enemy will see the gap and correct the next volley; your departure away from the burst will again cause an error in his aim."

In theory, this was clear. In practice, it turned out that I could never tell from the bursts when they were near or far.

I decided to watch my leader do an anti-aircraft maneuver. However, it turned out that what I had been strictly warned about happened--while I was maneuvering, I lost the leader and the other aircraft in the flight. But, there is no bad without good. The separation from the leader gave me an unexpected tactical advantage. The second fascist battery protecting the station was firing against three of our aircraft; either the enemy had lost sight of me or he thought I had been shot down. Be that as it may, I gained a relative freedom of action and again plastered the Hitlerite anti-aircraft gunners with cannon and machine gun fire. I belted them with short bursts and then immediately launched four rockets. They blew up right on the battery's location. While I was taking care of the anti-aircraft gunners, our formation had time to make two passes on the enemy trains.

Evidently, my first combat sortie was too much emotional excitement for me because I made a bad landing: I flared out high and at a low speed. The aircraft flopped down on the ground. "Maybe I retracted the gear," the idea flashed through my mind. But, the aircraft rolled along as if nothing had happened and responded to the controls and brakes. I taxied over to the hardstand safely. "Look, commander," the mechanic showed me a large dent in the armor plate. "There was evidently a direct hit from a fascist shell here and it was stopped by the Ural steel." The 53 holes I acquired during the sortie did not interfere with the aircraft's stability and controllability. It withstood everything during this flight, my failure-free IL-2: the hits from the enemy anti-aircraft guns and my crude landing.

As we pilots developed more faith in our ground attack aircraft and greater respect for its developers, it became more difficult for us to understand why the IL-2 was produced as a single-seat aircraft. "Hasn't there been some kind of a mistake here?" we thought. "It is obvious that there should be an airborne gunner to protect the aircraft from the rear!"

Of course, at the front, we did not know that the first prototype of the aircraft had been built as a two-seater and that S. V. Il'yushin and his assistants, the design bureau employees and the test pilots were convinced that it was necessary to have an airborne gunner defending the rear hemisphere. But, a lack of understanding of the ground attack aircraft's combat employment among certain leading military specialists led to the situation where a single-seat version was put into series production. As a result of this incorrect decision, the ground attack aircraft suffered unwarranted losses.

Soon afterwards, we received permission to reconfigure one of the IL-2's into a two-seater on our own. My first flight leader, Anatoliy Vasil'yev, and the squadron political officer, Capt Mikhail Pitskhelauri, initiated this project within the regiment. Volunteers from among the technicians built an aft compartment on Vasil'yev's aircraft. They put a macaroni box (as a seat) in the home-made compartment. They put ridges on it to strengthen it and cut out holes for the rudder cables. The machine gun was tied down with a telephone wire to an oarlock from a boat which was fastened to a hole in the fuselage. They ended up with a work place for an air gunner who could defend the aircraft against enemy fighter attacks in the rear.

Vasil'yev, the initiator of this remodeling effort and the "owner" of the aircraft, was to be the commander of this unconventional crew. Who would be the first person in the regiment to volunteer as the gunner? Everybody requested to go on this risky, experimental flight; but, Vasil'yev made his own decision: "The commissar will go!"--he said, thereby showing his special trust in Capt Pitskhelauri.

Vasil'yev and Pitskhelauri did not have any luck at first: they did not encounter the enemy for a long time. But then, two Messerschmidts pounced on the solitary IL-2 from the rear, out of the sun. The fascists did not even think about head-on attacks after their first encounters with our ground attack aircraft in the air; the ground attack aircraft had such a powerful forward-firing capability that it immediately brought the unlucky devotees of such actions to their senses. But, when the enemy made a pass on our uncovered tail, we frequently wound up in a difficult situation.

But, this time the enemy made his pass from the rear hemisphere and simply opened fire at a large distance. Without paying any attention to the tracers, Vasil'yev flew the aircraft almost straight ahead, giving the gunner an opportunity to aim better. Perhaps he understood better than Pitskhelauri did that the gunner only had a second in an engagement with aces; but, it was necessary to conduct the experiment right up to the end. The Hitlerites evidently had the ground attack aircraft in their sights good: the bullets were beginning to penetrate the skin. "Is Pitskhelauri dead?" the alarming thought flashed through Vasil'yev's mind and he wanted to put the aircraft into a steep bank when the machine gun began to chatter behind him. The commissar had bided his time and fired a pointblank burst from the machine gun at the Messerschmidt. The black fighter with the yellow underside dropped below the ground attack aircraft, went into a spin and exploded when it hit a hill.

According to the rules of engagement, neither Pitskhelauri nor Vasil'yev watched the shot down aircraft--while you're looking, they'll get you. They concentrated all their attention on the second Messerschmidt which had gotten into the saddle in the rear. They fought off one attack and then another. Vasil'yev made a high-G maneuver but the enemy did not drop behind. The G-load shook the metal; the air frame was strained to the maximum. With a dreadful force, the G-load pushed Vasil'yev into his seat. It was even more difficult for Pitskhelauri; he was sitting with his back to the direction of flight and did not know what the pilot's attentions were in this maneuver, but, he held on. To save rounds, he only fired in short bursts and then even used the flare pistol. Evidently, the fascist pilot took the flare for a rocket and he banked to the side and fell behind. This time, although Pitskhelarui did not shoot down the Messerschmidt, he undoubtedly gained a psychological victory over the enemy.

Later, experimental combat sorties were flown in the two-seat ground attack aircraft with the home-made compartment. Each of these flights reconfirmed the requirement for an air gunner on the aircraft.

A detailed report on the results of these flights was sent to the People's Commissariat for the Aviation Industry and to S. V. Il'yushin's design bureau. Evidently a lot of letters like ours had arrived at the design bureau. They confirmed the designer-general's opinion: the ground attack aircraft must be produced as a two-seater. The regiment received a thank you letter from the Experimental Design Bureau and the two-seat IL aircraft soon arrived in our squadrons.

With the air gunners, our job in combat was more confident and reliable. The IL-2 thus developed into a ground attack aircraft in the sense which the designer had evidently considered most feasible from the very beginning. The idea of ground attacks from the air was first completely realized in the hail of fire which the IL's rained down on the hated occupying forces. The IL's invincibility made it possible for us to fly right into the very thick of the anti-aircraft fire. Their high maneuverability made it possible to aggressively attack not only land targets but also enemy aircraft in the air, including his best fighters, the Messerschmidt-109 and the Focke-Wulf-190.

At one of the field strips near Volokolamsk, rain and snow drifts seriously inhibited flying. True, the snow melted quickly, adding a flow of mud to the front line roads. And, our flight strip became thoroughly "limp." The mud clogged up the oil coolers during taxing and take-off and, because of this, the oil temperature increased sharply in flight. But, our engineers and technicians found a way out: "Take off with the oil coolers closed," one of them advised our pilots, "and open the ducts when you are airborne."

This is what we did and it helped us get out of that situation. When necessary, we made use of this simple procedure up to the end of the war. Just as we made use of other innovations which were suggested to improve our methods.

I remember, for example, the following case where the IL-2 was put to original use. When there was a spring thaw, the roads were bad and we had to deploy to a new airfield. We did not rely very much on tracked vehicles or, even less, on wheeled vehicles for the relocation. We usually had to make do on our own. The mechanic or technician was put in the aircraft bomb bay and then the doors were tied up tightly with wire on the outside. The other specialists were put on the struts in the gear-well, after the retracting mechanism located in the cockpit had been disconnected so the pilot would not accidentally retract the gear in flight.

The ground attack aircraft performed all kinds of missions! On numerous occasions they were used as reconnaissance aircraft. The photographic missions were especially difficult.

Prior to the Belorussian offensive, I was summoned by the regimental commander. There was an urgent requirement for large-scale photography of the fascist forward defensive line. Our land forces really needed these photos. (However, oblique photography was a new job for us.) I took off and headed for Mstislavl'. Over the city, I joined up with three elements of our fighters. Accompanied by the escort, I descended and set up a maneuver to fly along the enemy's FEBA at an altitude of 50 m. The fighters were descending but not very willingly; evidently they did not completely understand my plan; but, there was no time for explanations. Right under the eyes of the fascists, I flew along the front line and Lt Pavlin did the photographs from the gunners compartment.

Our aircraft was taking hits from anti-aircraft guns, large caliber machine guns and tanks were firing at us. Evidently, everybody that had a gun was firing because different colored tracers were appearing ahead of, to the right, left and rear of the aircraft. I heard several direct hits. Finally, we completed the first pass.

I turned on a reciprocal heading and started a second pass at an altitude of 20 m. The entire aircraft was again surrounded by smoke from the shell bursts. On the third pass, I went even lower. The fascists intensified their fire. We should have made a maneuver but it was out of the question--we wouldn't get any photographs. So we flew along in a sea of fire. A little piece of hell, fragments from the shells were beating along the aircraft. The seconds seemed like an eternity. But, the third pass was over now. I left the front line and began climbing.

The photographs of the enemy's forward defensive line were outstanding; the mechanic counted over 200 large and small holes in the aircraft. The left wing was completely in tatters; only patches of the stabilizer were left; but, after all this damage, the aircraft was still able to continue flying and I was able to make it safely to our home base.

Other cases also testify to the exceptional invulnerability of the aircraft and its engine.

Here is what V. D. Artamonov, Hero of the Soviet Union and pilot-navigator in the 165th Guards Ground Attack Regiment, had to say about it.

"During one of our combat sorties near Kursk, my aircraft was shot down by anti-aircraft artillery fire. I was able to land it right at the FEBA, near enemy artillery emplacements. While I was getting a tank from our side to tow the aircraft further away from the enemy, he opened up on it with mortars. When I drove up to the aircraft in the tank, it was an extremely sad sight. One of the wings had been torn off, the propeller was knocked off, the engine was damaged, the cockpit was disfigured and the other wing, the fuselage and the tail section were literally riddled with holes from the mortar fragments. A mortar exploded near the left gear strut and the aircraft dug into the ground. Naturally, towing it was out of the question; especially since the enemy had detected us near the aircraft and opened up with intense mortar fire again.

I bid a regretable farewell to my reliable combat friend and returned to the regiment. Now, as a 'man without a horse,' I had to fly in other people's aircraft. The ground attack aircraft continued their intense combat operations during the Battle for Kursk. Once, much to my surprise, I saw something resembling an aircraft in my empty revetment: the remains of an airframe without wings, tail, cockpit or engine. I was even more surprised when the regimental commander told me: 'This is the aircraft you flew; fix it up and fly it. I'm not going to give you any other aircraft.'

Our miracle working technicians accomplished this assignment. Time passed and I was again flying sorties in my aircraft; gradually, I caught up with my comrades in arms in number of sorties.

Of course, the aircraft, which was halfway made up of spare parts, was hard to control and not as maneuverable as a new one. It took another 900 holes or more in combat; it was all patched up; but, I flew 93 combat sorties in it. It finished its glorious flying service near Kiev. But, it continued to serve after this. Having lived out its combat life, this veteran became a target at the range: it was used to train young pilots to strafe and bomb."

Lt. N. I. Dolzhanskiy, my wingman and I once engaged a pair of enemy fighters. The battle was unequal and Dolzhanskiy's aircraft was shot down. I saw a wide stream of oil and water coming out of the engine. There was no flame but my wingman's aircraft was obviously losing speed and altitude. There was a thick woods below us; there was no choice. Dolzhanskiy made a forced landing and his aircraft disappeared in the woods. I saw the swath his aircraft cut. A landing among tall trees did not bode well. However, due to the aircraft's strength, everything turned out okay. The armor which encompassed the cockpit and the gunner saved the crew and they returned safely to the regiment.

Another case also testifies to the aircraft's superior strength and its engine's endurance. During the battles to liberate Yugoslovia, I was in a ground attack aircraft formation on its way to destroy a column of retreating enemy tanks. The target was detected in the mountains southwest of Belgrad. While attacking the tanks, the ground attack aircraft came under intense enemy anti-aircraft fire. I felt a hit in the aircraft engine nacelle and then saw cracks, which remeinded me of frost on the canopy's glass; I smelled the typical aroma which accompanies an anti-aircraft shell burst. It was clear that I had taken a direct anti-aircraft hit in the engine. I handed over control of the formation to my deputy and left the target area aware that I had very little time left if the engine was damaged. The engine began to miss. The oil temperature increased but its pressure stayed steady; there was the smell of steam and of something burning in the cockpit. It became clear that the cooling system was damaged. The engine thrust dropped and the aircraft began to loose altitude. There was an unbroken string of mountains covered by snow below me; the snow was several meters thick in the canyons. I tried to change the engine rpm's; I tried to go over to booster; and I tried to change the throttle position. I was not able to reestablish stable engine operations; but, periodically, the engine came up to full rpm and the aircraft accelerated, climbed and then dropped again. We continued flying like this, which probably even surprised my gunner, until I suddenly saw a level white patch off to the side on the ground. I immediately turned toward it and saw a frozen lake surrounded by very old trees. There was no other way out; I slipped between the trees and two of them cut off the wings; I landed on the ice without putting the gear down.

It turned out that the water line leading to the radiator was completely cut. I was about 20 km from the target. The engine carried us all this time with just the oil to cool it.

After the engine, radiator and wings were replaced, I took off from the lake in this aircraft.

A case at least as interesting occurred when our ground attack aircraft were making a raid on Bogodukhov Station. My aircraft wound up in the anti-aircraft firing zone. A bright burst blinded me--the shell hit the sight pin which was located forward of the bullet-proof glass. The glass stood up under the shock from the explosion and the shell fragments. It seemed like everything had come out okay and we could continue the attack. We delivered our strike and returned to home base. I taxied over to the hardstand. A technician came up to the aircraft and suddenly shouted: 'Commander, how did you make it safe and sound?'

The armor protecting the fuel tank, which was located forward of the cockpit, had a hole in it; the tank itself, and the armor plate over it, was smashed. This was a direct result of the anti-aircraft shell's exploding on the fuel tank. The aircraft did not blow up and there was no fire due to the neutral gas system which filled the free space in the fuel tank; the designer had especially designed this system into the aircraft for this purpose.

The IL-2's endurance, its survivability and its ability to take off from poorly prepared fields and land on limited strips came to the rescue of ground attack pilots on numerous occasions. There are some cases which are widely known in the history of ground attack aviation where pilots have saved their comrades who made forced landings on enemy territory. It was not possible to select a site to land and take-off in these cases: they landed and took off from such small areas and uneven ground that it was only possible to marvel at the aircraft's maneuverability and the pilot's skill.

The IL-2's firepower was used to destroy tanks. During the first days of the war when the enemy had a significant numerical advantage in tanks, our ground forces destroyed enemy tanks by direct gun laying and they used anti-tank guns, grenades and Molitov cocktails, while the ground attack aircraft delivered strikes far behind the front lines: against railroad trains, in disembarkation areas, at concentration areas, on the march and in approach march formations.

Even during our counteroffensive at Moscow, the German General Guderian's tank formations took a lot from the red-starred ground attack aircraft. During three months of combat near Moscow, our ground attack division alone destroyed hundreds of enemy tanks.

By the time combat was getting underway at the Kursk Salient, we had large numbers of hollow-charge anti-tank bombs which were able to penetrate the thickest tank armor. These bombs were hung on the closed bomb bay doors and dropped on the fascist Tigers and Panthers; these were the enemy's latest tanks and the Hitlerites believed that the large-scale, surprise employment of them at Kursk would bring them success. But, Hitler's celebrated Tigers burned under the strikes by our ground attack aircraft with the anti-tank bombs, at first at Kursk and Orel and then along the entire Soviet-German Front where the strategic initiative had completely and definitively shifted to our forces.

During the grandiose battle at the Kursk Salient, the success of our ground forces, which absorbed the first strike by Hitler's hoards, was to a great extent facilitated by the aggressive operations of our air forces.

The effect of the IL-2's combat employment was staggering. Firing their guns, machine guns and rockets and accurately dropping hundreds of kilograms of bombs, the ground attack aircraft destroyed enemy manpower and equipment.

A situation frequently developed where it was not advisable to carry out combat operations in large formations of ground attack aircraft. For example, under adverse weather conditions when it was impossible to operate in large formations, small forces of ground attack aircraft inflicted significant damage on the enemy. Thus, at the beginning of 1945 in Eastern Prussia, two 6-ship formations of ground attack aircraft detected 30 enemy tanks under low cloud cover and limited visibility and destroyed eight of them.

When attacking tanks or self-propelled guns, various methods and tactics were used depending upon the location of the enemy tanks at the time of the ground attack aircraft's strike. We usually tried to attack from the rear where the armor was thinner and where the most vulnerable components of the vehicles were located: the engines and gas tanks. We took into account the tanks' anti-aircraft cover which usually consisted of self-propelled automatic anti-aircraft guns.

We usually attacked tanks on the march (in columns) from a straight approach or we used S-turns and sometimes a circuit. In concentration areas or during refueling, we usually used a circuit or, rarely, a figure eight. We usually operated against combat formations of tanks from a circuit in formations of 8-12 IL-2's. The greatest effect was achieved by using anti-tank bombs dropped from an altitude of 100-150 m.

Thus, in the summer of 1943, an 8-ship formation of IL-2's commanded by Guards Capt Smil'skiy dropped anti-tank bombs on 70 enemy tanks which were defiladed and massed for a counter attack. The ground attack aircraft burned more than ten tanks and disrupted the enemy's attack.

In October 1944, a formation of 18 IL-2's flew out to destroy enemy tanks which were preparing for a counterattack near one of the stations on the Shaulyay-Memel' Railroad. Capt Karpov, the formation leader, detected about 60 haystacks or bushes dispersed in checkerboard fashion in the target area. Tracks led up to each of these 'bushes' and disappeared under them. Gun flashes could be seen from the 'bushes.' The leader understood that these were the tanks. During their first attack, they dropped HE bombs and during their second attack, they dropped anti-tank bombs; then, the ground attack aircraft descended to lower altitude and attacked the infantry on the tanks. As a result, 12 tanks were set on fire. The enemy's counterattack was disrupted.

In the summer of 1944, the enemy had prepared a counterthrust in the Shaulyay-Memel' sector and he intended to make use of the adverse weather conditions which inhibited the employment of our air forces. To deliver the counterthrusts, the fascists had moved forward a large formation of ground forces reinforced by several dozen tanks.

In four-ship formations of IL-2's, the ground attack aircraft delivered a number of consecutive strikes against the enemy tanks. Because of the low cloud cover, the attacks were conducted from straight and level flight at altitudes below 100 m. They delivered a strike using anti-tank bombs against the area occupied by the tanks and strafed the enemy infantry with their machine guns and cannons. In spite of the adverse conditions, the ground attack aircraft destroyed and damaged 15 tanks and more than 10 motor vehicles; they suppressed 2 artillery batteries and inflicted heavy damage on the enemy's men. Exploiting the results of the strikes by the ground attack aircraft, our ground forces went over to the offensive, disrupted the enemy's counterthrusts and occupied a number of populated areas.

The superior combat capabilities of the IL-2 ground attack aircraft not only made it possible to wage successful combat against enemy tanks but also to destroy armored trains.

In July 1943, an enemy armored train at Tereben' Station was delaying the advance of our forces with its fire. Two flights of IL-2's commanded by Lts Belyakov and Ryzhov flew out to destroy the armored train. It was detected at Buki Station. It was made up of four armored cars with an engine between them. Four ammunition flatcars were located 300 m from it. Everything was thoroughly camouflaged against the background of the surrounding woods.

To make sure that the target they had detected was the armored train, the ground attack aircraft made a dry run. The enemy opened up with anti-aircraft fire. Then, the ground attack aircraft reformed into a circuit and began sequential, single-ship attacks from an altitude of 200-500 m. Encountering no further opposition from the enemy armored train, our forces continued their offensive.

The following episode, which was very well known among front line soldiers, testifies to the effectiveness of the ground attack aircraft operations. A 7-ship IL-2 formation commanded by Lt Dolgov delivered a strike against Shepetovka railroad junction where 14 trains were massed. The ground attack aircraft operated without fighter cover since there was dense cloud cover at an altitude of 400 m and above and the visibility was approximately 2 km; this precluded any opposition from enemy fighters. The formation arrived at the target and they all delivered a simultaneous gliding strike. About 30 cars were destroyed or damaged and there were severe explosions and fires among the trains. The ground attack aircraft did not sustain any losses. The fires and explosions at Shepetovka Station continued without any let up for 3 1/2 hours; as a result, all 14 enemy trains were destroyed. The explosion of three cars with explosives on board destroyed five adjacent tracks, the railroad repair depot and other buildings. A large crater was formed at the site of the explosion. The entire railroad junction was put out of commission.

The destruction was so great that the enemy was not able to bring the damage from the ground attack strike under control and by the time the station was occupied by our forces only two tracks had been restored for trains to move along.

In October 1944, while trying to stop the subsequent advance of our forces, the enemy concentrated a large number of infantry, tanks and artillery, as well as an armored train, near Mazheykyay. While moving within a sector of the Kurmanitse-Mazheykyay Railroad which paralled the front line, the armored train was interdicting the 4th Shock Army's advance with its fire. As a result of the very first attack, there were several explosions on the armored train and the engine was surrounded by clouds of steam. During the third pass, there was a severe explosion on the armored train and the fire from this explosion extended to a great height. The ammunition flatcars were also blown up. The ground attack aircraft returned to their airfield without any losses; the ground forces command element reported that the armored train was not firing and our infantry was successfully advancing.

For a short period of time, the ground attack reconnaissance aircraft were not able to detect the armored train. The enemy moved its location frequently and thoroughly camouflaged it into the surrounding terrain. It was Lt Kuznetsov, the leader of a four-ship formation of ground attack aircraft, who noticed the armored train. While flying at an altitude of 100 m, he detected a break in the roadbed which was overgrown by branches of trees. Kuznetsov decided to fire at the suspicious-looking bank. After opening fire, he paid attention to the bursts caused by the shells hitting the bank--the branches were camouflaging the armored train. During their first pass, the ground attack aircraft destroyed the tracks on both sides of the armored train; during subsequent attacks they damaged the engine and smashed up the armored tender, the artillery platform and the anti-aircraft gun.

In 1943, the ground attack aircraft began to be used more frequently, not only for operations on the battlefield but also in the enemy's rear. One of the difficult operations was attacking airfields. I remember when our 233rd Ground Attack Division was assigned a responsible mission: destroy the fascist aircraft at Shatalovo Airfield. From this base, the fascists were delivering strikes against Soviet forces and conducting reinforced reconnaissance flights in our rear. In addition, our reconnaissance reported that there were many fascist bombers there and over 10 POL and ammunition trains.

...It was still not light when the duty officer got us up. The pilots and air gunners assembled within a few minutes. The technicians had already prepared the aircraft for flying.

During these difficult four years, the engineers and technicians work was made easier by the aircraft design which had been thought out very well down to the last detail. The large hatches quickly gave free access to the primary aircraft and engine systems and assemblies. Not a single aircraft besides the IL-2 could be repaired so quickly under front line airfield conditions. A bent propeller was straightened out with a sledge hammer, the engine was tested on the ground and the aircraft was launched. It turned out that this aircraft would subsequently fly dozens of combat sorties. Wings, half a fuselage and tail sections were replaced under field conditions. During a single cold night, they could put in a new engine and launch the aircraft in the morning. The simple gear design was reliable. If you taxied along a muddy taxi-way in any other modern aircraft, the gear would not retract later. The gear on the IL-2 withstood everything: crude landings, any roughness, punctured wheels and the "rolling" during the landing run. The pilots joked: "You can begin taxing the IL-2 at an altitude of 50 m." Moreover, there were forced landings without airfields, without gear, belly-in and, moreover, in the woods, ravines or hills! It seemed like only a miracle had saved the crew when it was painful to even look at the aircraft. But, both the aircraft and the crew were usually returned to formation. This was a miracle made by man: by the designer's talent multiplied by the selfless work of our engineers and technicians and the expertise of the pilots who were able to bring a 'wounded' aircraft back to friendly territory under the most difficult conditions.

An aircraft's invulnerability is a very valuable characteristic during war. The IL-2 ground attack aircraft was completely invulnerable. Was this considered the most important thing in developing a battlefield aircraft?

Even in February 1940, when everything was ready to put the new ground attack aircraft into series production, skeptics were saying that the IL-2's speed and altitude capabilities were too low. However, even then, the designer was convinced that the ground attack aircraft was not a fighter and it had other distinctive characteristics. A ground attack aircraft required cannons, machine guns, rockets, bombs and, most importantly, armor, which would make it possible to employ all these weapons on the battlefield. But, the skeptics declared that 6-12 mm thick armor was poor protection. The designer proved that the armor would not function alone but in combination with the specific configuration of the entire aircraft, with sufficiently high speed and high maneuverability. It was this totality of the most diverse design solutions which provided the IL-2's unsurpassed survivability, which had never been seen in domestic or foreign aircraft production...

...Now, we were in the cockpits of our combat aircraft. The primary mission of the ground attack aircraft was to penetrate to the target through enemy fighters and anti-aircraft fire, deliver their lethal cargo to the objective, deliver it on the enemy, smash his will power, crush the Hitlerites military hardware and destroy the enemy. Everybody knew his mission and everybody was ready to carry out the operations order to the best of his ability.

A single opinion on the location of fighter cover had not been developed at that time; but, I always stuck to the principle that the fighter cover leader knew where they should be located.

Our low-altitude, surprise attack tactics were successful for us. The Hitlerites were not expecting our raid. The airfield was just beginning to stir. There were aircraft packed close together on the hardstands. Evidently, the enemy anti-aircraft gunners were 'sleeping through' our arrival. They did not fire a single shot while we were making our passes on the target. But, now, the first formation of ground attack aircraft had dropped delayed-action bombs directly on the fascist bombers. A few seconds later, there was a powerful explosion. The enemy aircraft were burning. The airfield was shrouded in black smoke.

A few seconds later, the second formation made a pass on another hardstand. From a distance, they opened up with their cannons and machine guns against the closely packed fascist aircraft. After getting closer, they dropped bombs from a single pass. These aircraft were transformed into a large pocket of fire. The fascists were not able to save a single aircraft. Everything was enveloped in smoke; only large tongues of flames were visible through it.

Fiery chains stretched out in pursuit of the departing aircraft--Hitler's anti-aircraft batteries had finally opened fire. This time, the anti-aircraft gunners had guessed our maneuver and they knew that we were returning for a follow-on attack; They put up a curtain of fire in front of us. Our air gunners counted 500-600 bursts in the sky through which we had to fly.

It was not easy for the flight leader and his wingman to direct their aircraft straight into a tongue of fire. It was even more difficult to do this with an aircraft which was photographing the post-strike results. The enemy was naturally trying to get revenge for the damage done. He was directing all his fire at the airborne photographer. But, an order is an order: the results of the raid had to be recorded. After turning on the camera, I tried to fly precisely over the aircraft hardstands which were enveloped by flames.

Suddenly, I felt a severe impact on the fuselage and, 5-10 seconds later, another one on the left wing.

But, the aircraft was flying and I was maintaining the prescribed course. I could not see any smoke or fire. That meant I was not burning. The gunner shouted something, but it was impossible to make it out in this chaos. Our ground attack aircraft jerked again severely--a third direct hit. This time, smoke burst into the cockpit. My throat was dry and I couldn't breath; but, I decided to endure it and fly straight ahead several more seconds and accomplish the mission before jerking the aircraft to the right or left, down to the side in order to somehow attempt to get out of this fiery hell.

Through the din of the engine, I heard the machine gun chatter. It was JrLt Smirnov, my gunner, firing at the anti-aircraft crews. 'Good show!' I praised him over the intercom system while I pushed the stick forward and put the aircraft into a slipping descent. But, for some reason, it was hesitantly reacting to the change in the position of the controls; it was banking to the left. I looked at the left wing. Jagged edges bristled on the wing tip. The port aileron had a gaping hole in it and the canvas strips were fluttering in the airstream like they were alive. The gunner reported that the fuselage had a large hole in it.

I cautiously tried the controls. Although sluggishly, the aircraft responded. My wingman was sticking with me. I asked him:

'Babkin, how are you?'

'Okay, commander; only, for some reason, my gunner is silent. I will fly ahead and you look and see what's wrong with him.'

I throttled down and let my wingman go ahead. Although white as chalk, his gunner was smiling and giving a thumbs-up sign. The other formations took no losses while Hitler's primary airfield was put out of commission for a long time. This was confirmed by our post-attack photography and by a reconnaissance report which arrived later.

As is well known, the IL-2 ground attack aircraft began to enter line units at the beginning of the war. It was mastered and ground attack tactics were developed during combat operations. In the beginning, each commander taught his subordinates what he himself knew based on his own personal experience. But, gradually, the best tactics became accessible to everybody. Thus, common efforts led to the discovery of the 'circuit' combat formation. The ground attack aircraft formed up in single file over the objective and dived on the enemy one after the other. Then, the first aircraft caught up with the last one in the file and the aircraft again took turns assaulting the enemy. We had a closed loop and not a single enemy fighter dared attack our combat formation and run into the concentrated fire of the gunners from the other aircraft. We formed up into this 'circuit' while we were flying in 4-ship, 6-ship, 8-ship and larger formations when attacking Messerschmidts and Focke-Wulfs.

The enemy anti-aircraft gunners gave the ground attack aircraft a lot of trouble. They tried to hit our aircraft at the instant we transitioned into a dive or when the aircraft were climbing while recovering from a dive. When conducting raids on enemy objectives with good anit-aircraft cover, our squadron began to form a two-group combat formation. The covering group suppressed the anti-aircraft guns while the main group assaulted the assigned objective. This simple tactic was very effective.

To provide greater safety for ourselves against possible losses from the anti-aircraft guns, we also introduced maneuvering in information which gave each pilot the opportunity to continually change his altitude (fly higher or lower than the flight leader), reduce and increase intervals between aircraft and even turn slightly away, within permissible limits of course.

This was facilitated by the exceptional ease in flying the IL-2 and the simplicity in operating it. The process of flying it was not difficult. When operating over the target or in air combat, the pilot's attention was not distracted by any difficult manipulations of instruments or equipment in the cockpit. The aircraft even made it possible to make gross flying errors, which was very important when the pilot was carrying out an attack or engaged in combat and did not have time to watch the instruments. I do not know a case where an aircraft lost its controllability or went into a spin due to errors in flying procedures. This aircraft was a godsend for training new flying and technical personnel under the most difficult wartime conditions; it ensured the uninterrupted reconstitution of combat losses.

Throughout the entire war, the combat operations of ground attack aircraft usually took place under strong opposition from fascist fighters. The ground attack aircraft's ability to get through them was just as important to us as suppressing anti-aircraft fire.

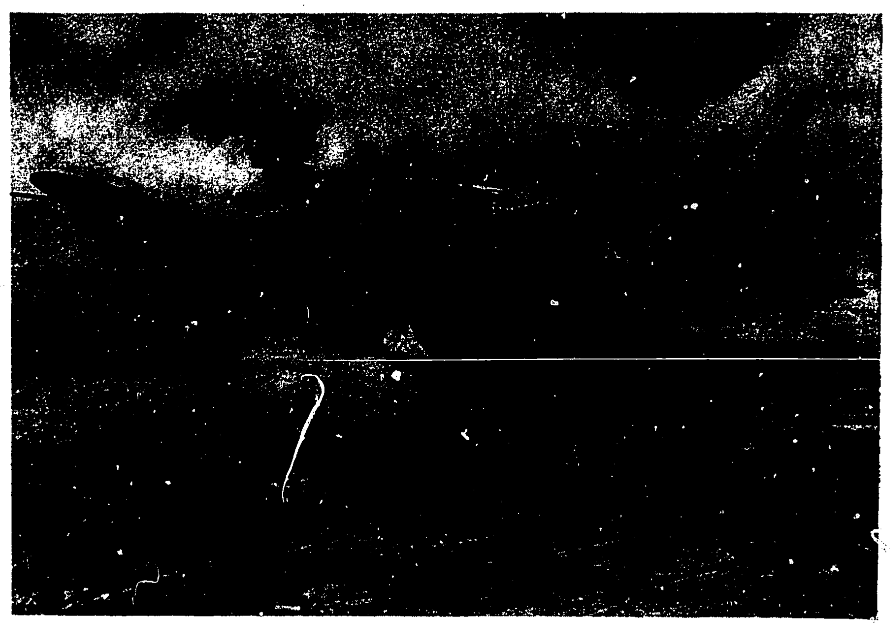
It was difficult for a heavily loaded ground attack aircraft enroute to the target to compete with a Messerschmidt in maneuverability. But, if forced by the situation, we also were not inferior to them. I personally engaged in 47 air battles and our aircraft was not damaged in a single one of them. I am obligated to my air gunners for this, especially Yuriy Dobrov.

There were numerous examples where Il-2's waged successful air battles against enemy fighters. Thus, a 6-ship formation of Messerschmidts jumped SrLt Vasil'yev's aircraft when he was flying weather reconnaissance. Maneuvering skillfully, our pilot directed precise fire against the enemy aircraft. The gunner, MSgt Ponomarev, did not lag behind the commander. They shot down one of the Messerschmidts and got away from the others by flying at low altitude.

In September 1942, a six-ship formation of IL-2's commanded by Capt Anan'in flew out to destroy enemy reserves south of Sychevka Station. The ground attack aircraft arrived at the target and delivered an accurate strike against it. While recovering from the attack, Lt Zhigarin noticed that two enemy fighters were attacking the lead element while two other Messerschmidts were covering them from above. Zhigarin warned the flight leader, turned quickly and beat off the enemy fighter attack with cannon fire and rockets. Five ground attack aircraft quickly formed up into a 'circuit' to repel the enemy fighter attack. The sixth pilot, Sgt Karbash'yan, whose aircraft had been hit by anti-aircraft artillery fire over the target, had broken away from the formation and was not able to form up with it. The Messerschmidts pounced on the damaged aircraft. Zhigarin hurried to his assistance and shot down one of the Messerschmidts with long bursts from his cannons and machine guns. The enemy fighters left the damaged IL-2 and began to attack Zhigarin's aircraft. Making use of this opportunity, Karbash'yan descended and headed for friendly territory. While engaged in high-G maneuvers, Zhigarin was evading the Messerschmidt attacks and he was approaching the rest of the aircraft in his formation, which was withdrawing toward the front line. The Messerschmidts cut off Zhigarin and did not give him a chance to link up with the formation. While already over the front line, Capt Anan'in saw three Messerschmidts attacking Zhigarin's aircraft and he led the remaining aircraft in the six-ship formation to his assistance. Approaching from the side and then from below, he shot down the enemy aircraft which had come especially close to Zhigarin's aircraft. Having lost two aircraft in the air battle, the enemy fighters broke off the attack against the ground attack aircraft.

In June 1943, a six-ship formation of IL-2 ground attack aircraft commanded by Capt Greben'kov, and escorted by ten YAK-7b fighters, delivered a strike against railroad trains. One of the IL-2's was shot down by anti-aircraft artillery fire. At the same time, the formation came under attack by enemy fighters: about 40 Fockke-Wulf-190 fighters joined the escort fighters in combat while ten Fockers pounced upon the remaining five ground attack aircraft. Employing the S and scissors tactics, the ground attack aircraft successfully repelled all the enemy fighter attacks and withdrew to the east along the Orel-Yelets rail line. During the defensive battle, Greben'kov saw the trail aircraft in his formation attack two Fokkers. With a combat turn, Greben'kov took up an advantageous position above the enemy and, from a dive, shot down the fascist fighter element leader. At that time, Greben'kov himself was being fired upon by an element of Focke-Wulf-190's. He fell behind the formation and was forced to repel the enemy fighter attacks by himself. The fascist fighters were continually attacking his aircraft but they were unsuccessful. By making skillful use of his aircraft's maneuvering capabilities and its fire power, Greben'kov broke away from the Fockers' pursuit and returned to home base.

S. V. Il'yushin and V. K. Kokkinaki, test pilot for all types of Il'yushin-designed aircraft.



The IL-2 ground attack aircraft--"the great workhorse of the war."

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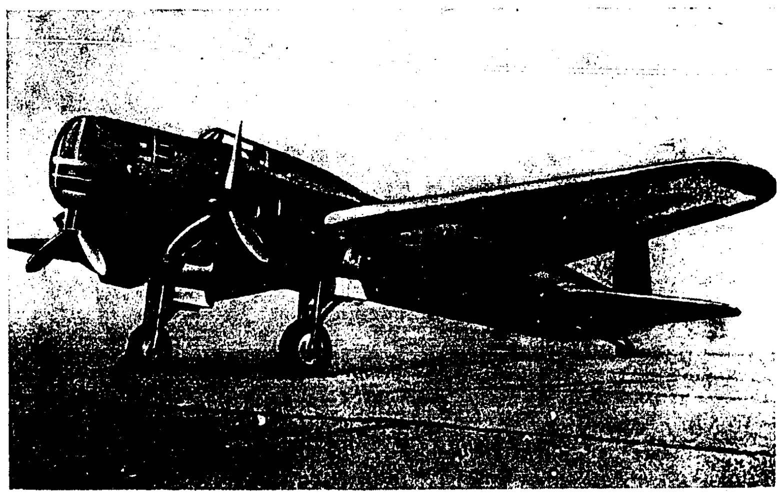
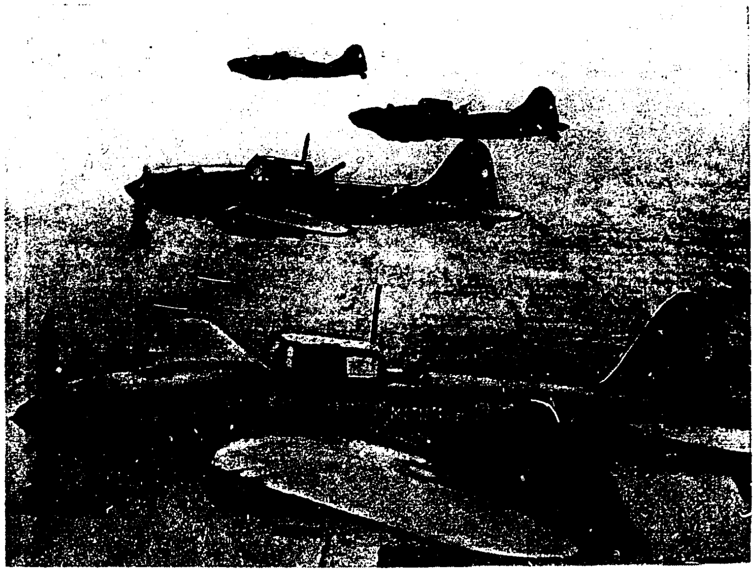


1. The Mastyazhart glider designed by S. V. Il'yushin.

2. The Moscow CDB-26 aircraft which made a nonstop flight from Moscow to North America.

1.



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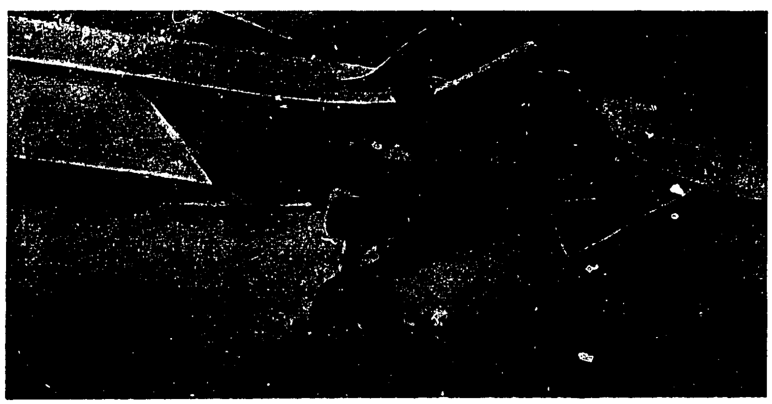

1. An IL-2 ground attack element on its way to carry out a combat mission.

2. A severely damaged IL-2 which returned to its home base.

IL-2 ground attack aircraft attacking the enemy from a dive.

1.

2.

1. The IL-10 ground attack aircraft with rockets.
2. The IL-20 ground attack aircraft.

S. V. LL

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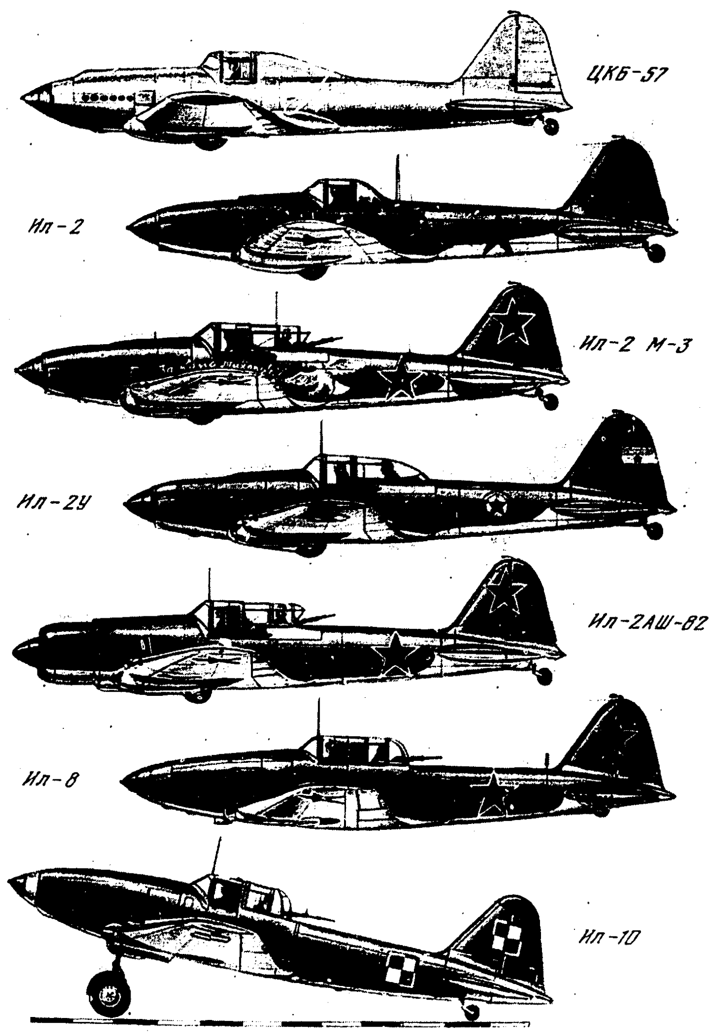
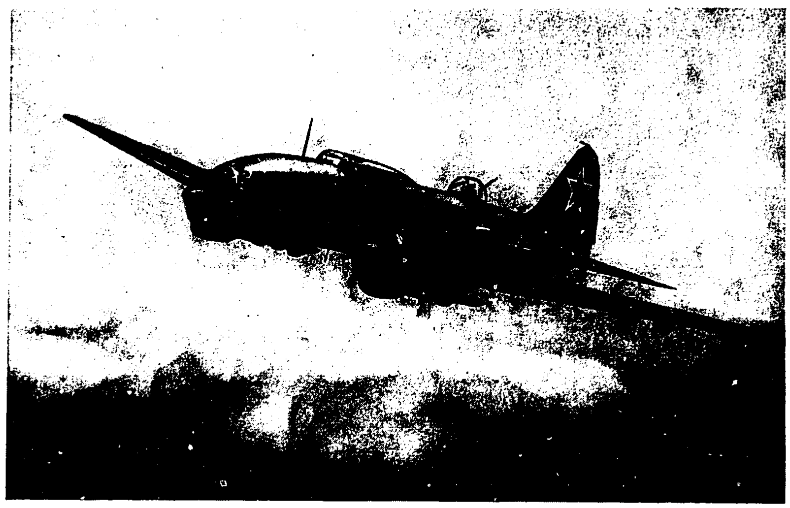


The Il'yushin family of ground attack aircraft.

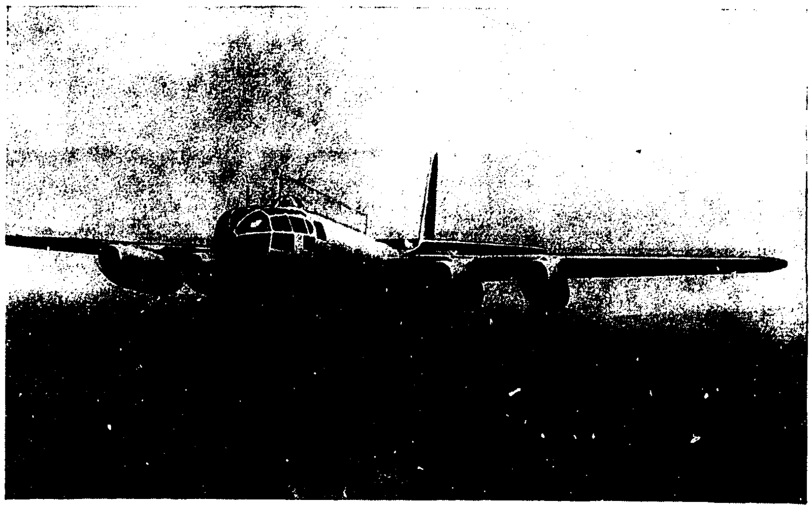
1.



2.

1. The IL-4 long-range bomber.
2. The IL-4 torpedo bomber.

1.



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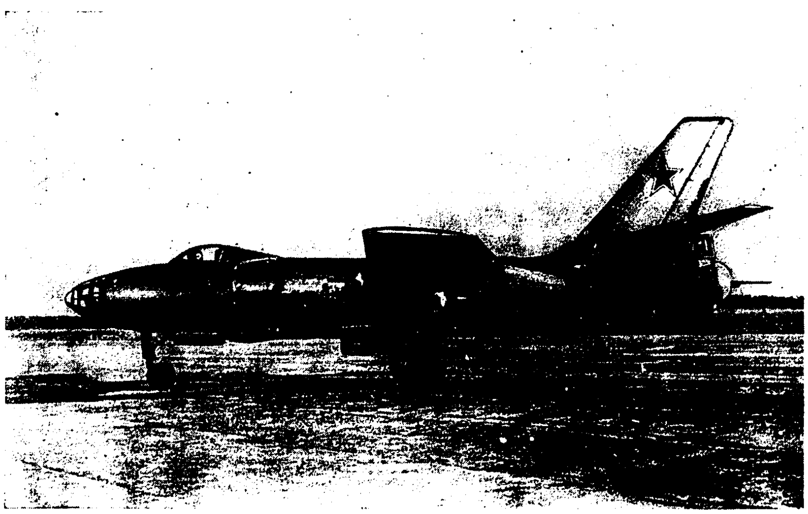
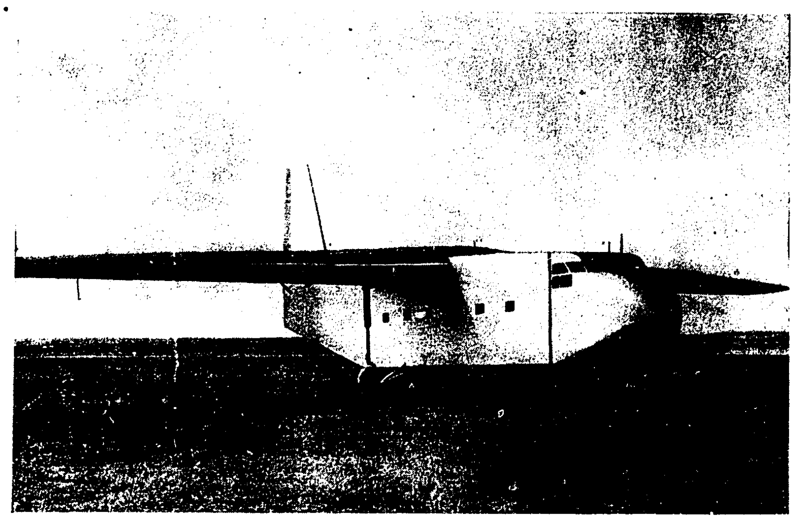


1. The IL-22 experimental aircraft.
2. The IL-28 tactical jet bomber.

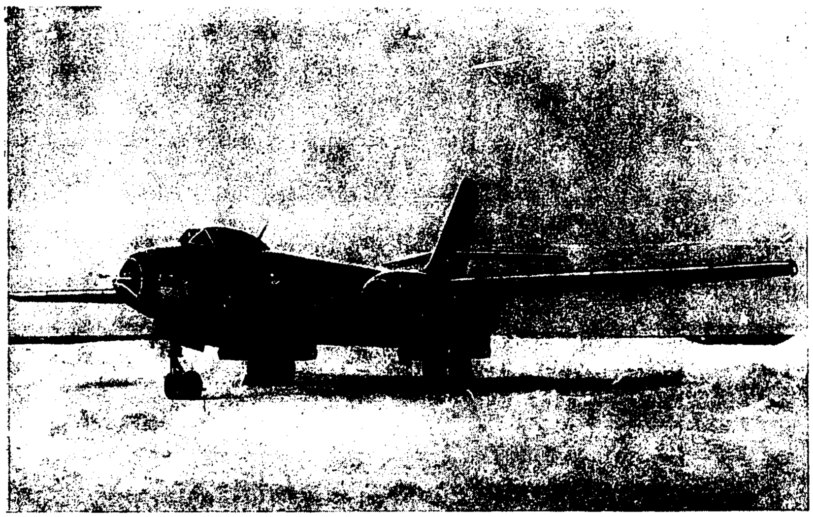
1.

2.



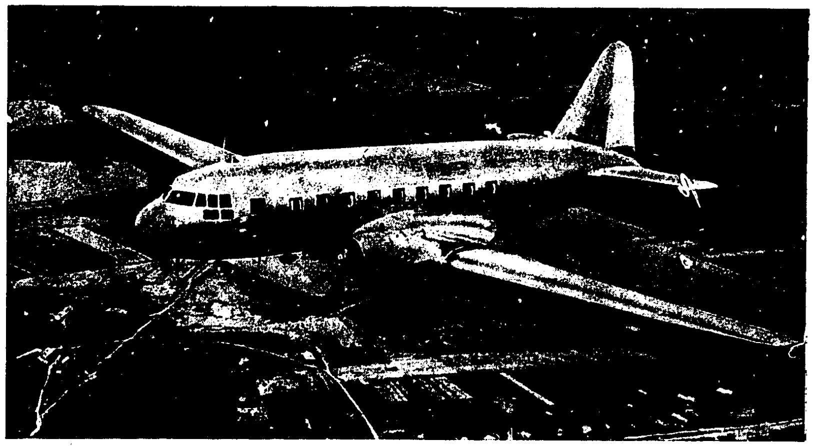
1. The IL-28R reconnaissance aircraft.
2. The IL-32 cargo glider.

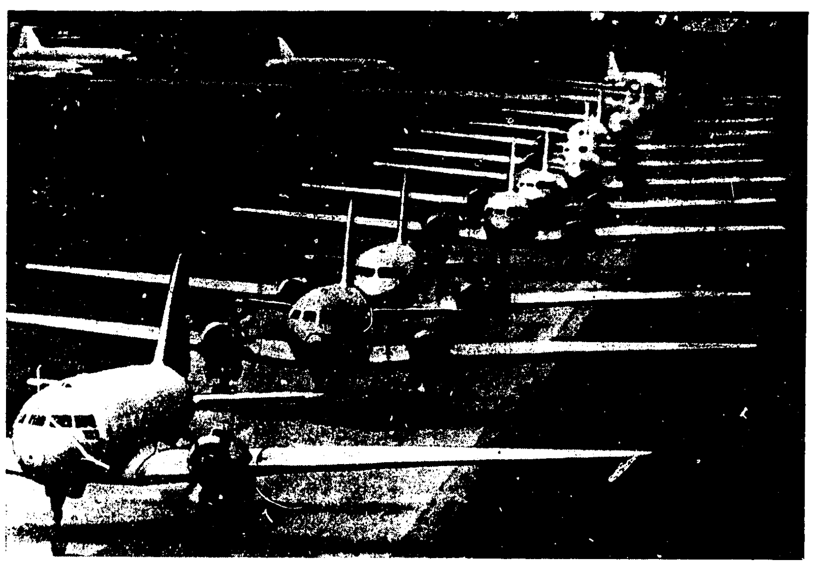
1.



2.

1. The IL-46 jet bomber.
2. The IL-54 jet bomber.





IL-12 airliners

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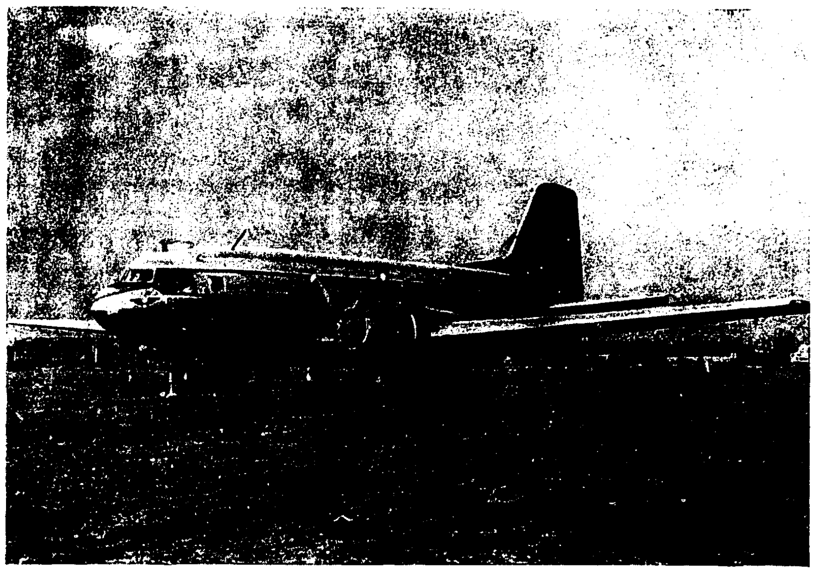

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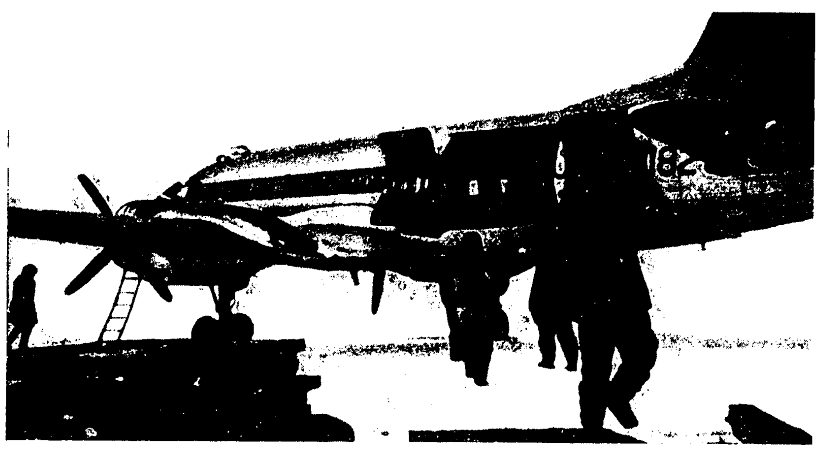
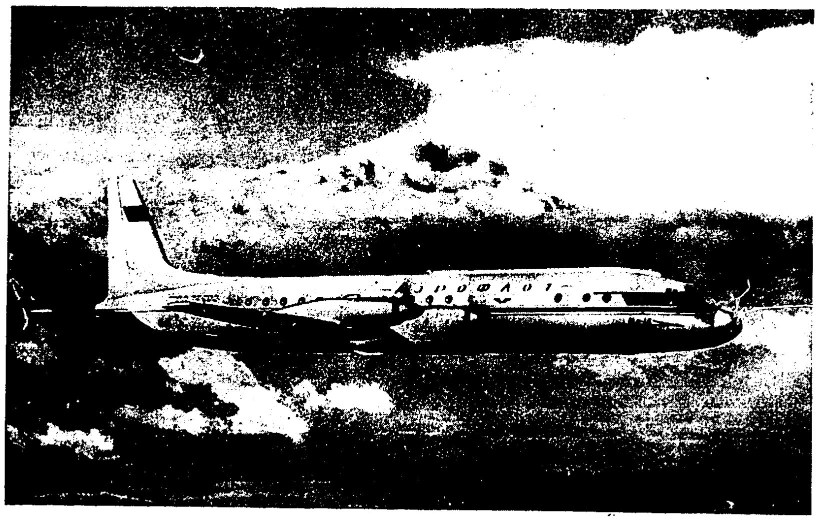


1. The IL-14 airliner.
2. The IL-14 cargo plane at the North Pole.

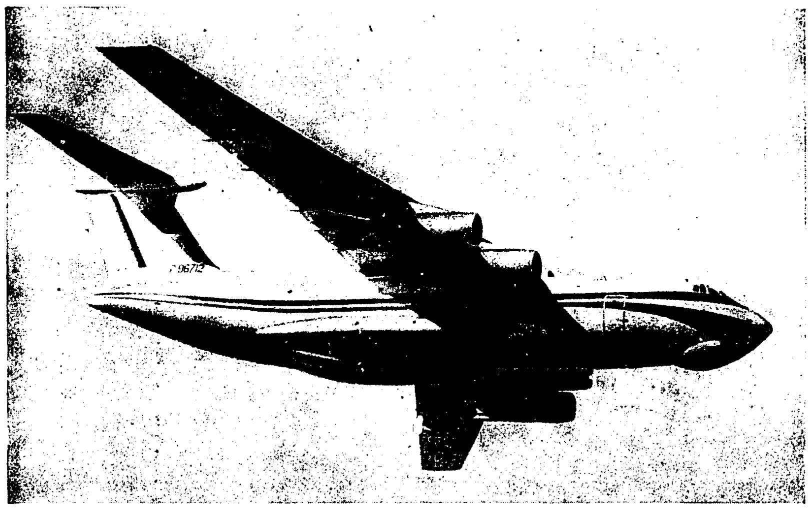


IL-18 turbo-prop airliners.

1.


2.


1. Thrust reverser on the IL-62M.
2. Interior of the IL-62M passenger cabin.



The IL-76 (on top) transport and the IL-86 airliner (airbus) which were developed under the leadership of Designer-General G. V. Novozhilov.

The armed forced newspaper KRYL'YA SOVETOV reported numerous astounding cases of IL aircraft combat sorties during the war. A 4-ship formation of ground attack aircraft engaged 18 German fighters in combat for 15 minutes. Our comrades-in-arms--the crews of SrLt Chernets and Novikov, Lt Pleshakov and JrLt Zubko--repelled over 40 attacks in the air. The ground attack aircraft not only beat off all the attacks by Hitler's pilots but they also shot down two Messerschmidts.

The IL-2 not only proved itself as a first-rate ground attack aircraft which was successfully employed to destroy enemy tanks, weapons emplacements and men on the battlefield but also as an aircraft which was able to wage aggressive combat against enemy bombers, fighters and transports.

Thus, an 8-ship formation of IL-2's commanded by Capt Nesterenko, escorted by 4 YAK-1 fighters, was on its way to deliver a strike against tanks located north of Krivoy Rog. While they were approaching the front lines, the corps commander ordered the ground attack aircraft to attack four 20-ship Junkers-87 enemy bomber formations being escorted by 8 Messerschmidt 109's. At that time, the enemy bombers were reforming to strike our forces.

Upon receiving the new mission, Capt Nesterenko led the ground attack aircraft to close with the enemy. The ground attack aircraft fired at the first bomber formation on the run and disrupted its combat formation, while the fighter escort joined the enemy fighters in combat. The second Junkers-87 formation was located 200-300 m higher than the ground attack aircraft; it attempted to attack our IL-2's from a dive. Nesterenko and his group had a margin of speed and they attacked the second bomber formation from a pitch-up. Four of the Junkers-87 were shot down and the formation's combat formation was dispersed. At that instant, the third Junkers-87 formation made an attempt to attack the ground attack aircraft from the rear. Nesterenko turned the ground attack aircraft on a reciprocal heading and headed for the Junkers-87 formation. The enemy could not withstand the head-on attack; he broke his combat formation and tried to withdraw after dropping his bombs in a haphazard manner. The ground attack aircraft continued their combat operations and shot down four more Junkers-87's. Altogether, the ground attack aircraft shot down eight Junkers-87's in this battle; but, the most important result was the fact that they had disrupted a strike by 80 enemy bombers against our forces.

After the air engagement with the bombers, Nesterenko's formation carried out its first combat mission--it delivered a strike against the enemy tanks and returned to its airfield without any losses. As shown by the war's experience, success in air combat was achieved primarily by using the IL-2's good maneuvering capabilities, its head-on firepower and the presence of the air gunner armed with an efficient, large caliber machine gun.

During the Great Patriotic War, ground attack aviation had a long and glorious history. Numerous heroic pages in the chronicles of the war were written by the ground attack aircraft. They were favored a great deal by our ground forces because, by anticipating the actions of tankers, artillerymen, combat engineers--who set up crossings--and the motorized infantry, they operated ahead of everybody and cleared the way for them.

I remember an exceptionally difficult operation by the 2nd Belorussian Front in a forced crossing of the Oder River and in the battle for a bridgehead on the other side of the river. This river had two rather wide, down-river branches with a swampy floodland in the middle. "Two Dnepr Rivers with a Pripyat' Marsh in the middle," this is how the veterans of the battles had accurately christened this obstacle.

In an exceptionally intense engagement, our fighting men cleared the enemy out of the area around the river while operating up to their waist in the swampy mud and by climbing on to the high spots and trees when the tide came in to the mouth of the Oder from the Baltic Sea. Naturally, under these conditions, neither the artillery nor the tanks were really able to assist our formations which were making the forced river crossing. But, effective assistance was provided to the advancing forces by the ground attack aircraft. With precise, low-altitude strikes, they completely destroyed the fascists' concrete emplacements, smoked them out of their concrete pillboxes and, with cannon, rocket and machine gun fire, destroyed Hitler's soldiers who were attempting to throw our advanced detachments back to the other side of the Oder. Our advancing forces had to overcome the fierce resistance of Hitler's troops. In the 37th Guards and 15th Sevoskaya Rifle Division sectors, the difficulties in supplying ammunition along the single, irregularly operating river crossing site at times gave rise to critical situations. Again, our infantry friends were assisted by our "winged tanks." The vectoring stations provided us with precise coordinates of where the strikes should be delivered. At other times, our missions were provided after we were already airborne and, 5-10 minutes later, bombs, rockets, cannon and machine gun fire rained down on the enemy, destroying his men and equipment.

The effectiveness of the ground attack operations received high marks from 65th Army Headquarters. Even more pursuasive was the opinion of MajGen K. Grebennik, commander of the 37th Guards Division: "If not for the exceptionally strong support from the ground attack aircraft," he said, "we would have been swimming in the Oder again."

Things reached a point where, after expending all our ammunition--bombs, shells, rockets and machine gun belts--we continued to fly over the battlefield at low altitude sowing panic and fear in the enemy camp and providing moral support for our forces.

I completed my last, 222nd combat sortie; the mission was to destroy enemy ships in the Baltic Sea near the port city of Swinemuende.

The IL-2 had carried me from the environs of Moscow to the Elbe on many occasions. This aircraft's superior combat performance made it possible for many pilots to display their skill, pluck and courage. Every third pilot who was awarded the lofty title Hero or twice-honored Hero of the Soviet Union was a ground attack pilot. Two out of every three airmen who were decorated with the Order of Glory, 1st degree, were air gunners in ground attack aviation.

The IL-2 did not have any peers at home or abroad. For the first time in the history of world aviation, the designer had been able to find that singularly correct combination of numerous operational features which made the IL-2 an unsurpassable support aircraft, a fighting aircraft.

I did not get to fight in the IL-10,which began to enter service in October 1944. But, the fact that this new IL was widely and successfully employed in the battles on German territory confirms its superior combat performance which was inherited from the IL-2. I did fly in the IL-10 after the war. My many hundreds of hours of flying time give me good reason to state that this was a threatening fighting machine--a worthy heir to the legendary IL-2.

The IL-2 was a classic example of a ground attack aircraft. Its development was not only a revolution in aircraft production but also in tactics, in the very nature of ground attack operations,an idea which arose during World War II but which might have been buried with the unsuccessful R-5SSS, I-15bis, I-153, SU-2 and other aircraft which were essentially not adapted for battlefield operations. In developing the IL-2, the designer thought about the tactics for ground attack aircraft, the conditons of combat operations which face them and their makeup. While visiting the front and meeting with pilots in his design bureau, Sergey Vladimirovich gave some useful advice on the aircraft's combat employment. I had numerous opportunities to listen to him during the battles near Moscow and later at the end of the war. We were always struck by how well the designer knew ground attack tactics, as if he had fought 'wing-tip-to-wing-tip' with us in a single combat formation. This is why the IL-2 became the primary aircraft in ground attack aviation and played a decisive role in routing the fascist forces during the Great Patriotic War.

Joint combat operations with ground forces confirmed the basic requirements levied on aircraft operating over the battlefield: precise destruction of small targets in close proximity to friendly forces; continual pressure on the enemy over an extended period of time; and destruction of those targets which our forces were most interested in at a given time.

These are precisely the requirements which the IL-2 satisfied better than other aircraft; it possessed the combat capabilities required for this purpose. The aircraft's most important advantage was its armor plating combined with good maneuverability. This made it possible to operate at low altitudes; it facilitated the search for and precise destruction of small targets under intense enemy anti-aircraft fire. The powerful, diverse weapons systems, a sufficient amount of ammunition and the necessary fuel reserves made it possible for the IL-2 ground attack aircraft to remain over the battlefield for a long period of time and exert extended pressure on the enemy. The large effectiveness of strikes against any objectives, combined with the ease of controlling airborne elements, made it possible for the ground attack aircraft to quickly respond to instructions received from the ground and deliver their strikes where assistance to our forces was required at any given time.

During the war, not very many of the front line pilots knew what S. V. Il'yushin's design bureau was doing. We only saw the aircraft which went into series production and arrived at our forward airfields. Obviously, there were also prototypes which were testing new ideas. We realized this very quickly since the jet IL-28 had already appeared in 1948 (a total of three years after the Great Patriotic War ended). This was a tactical bomber with a three-man crew: pilot, navigator and gunner.

We immediately appreciated and liked this new aircraft. I flew the IL-28 for several years. Although the highly increased envelope, operational employment under adverse weather conditions and at night and the electronic support landing system should have made this aircraft more difficult to fly, the ease in flying it even surprised the crews with average training. We would fly in it for a long time in the clouds and at long distances without seeing the target and precisely carry out our operational missions (in place and time). The aircraft was stable in flight and simple and responsive to the pilot during take-off and landing.

The operational experience with this aircraft, as well as with other aircraft, confirms the truth of the saying that the aircraft designer must not only be a scientist-aerodynamics specialist and engineer-technologist but also an outstanding tactician. Numerous years of experience have shown that only a knowledge of all the features of a future aircraft's operational employment will make it possible to develop aircraft which are completely responsive to their roles. These are precisely the aircraft which are produced in substantial numbers and which actually become great aircraft. Designer-General S. V. Il'yushin has achieved this.

CHAPTER 8

THE IL-2 GROUND ATTACK AIRCRAFT

A. V. Minayev (deceased), Lenin Prize Winner

Among the combat aircraft of the Great Patriotic War, the armored IL-2 ground attack aircraft occupies a special place. Not a single belligerent country had a similar aircraft and not a single aircraft was built in the same quantities as the IL-2. When he began designing it, Sergey Vladimirovich understood that it was not possible to protect the aircraft against all types of ground-based weapons with armor. Even the thick armor of tanks could be pierced by the appropriate caliber of ground-based artillery shells. S. V. Il'yushin was faced with a difficult problem: on the one hand, it was necessary to select an armor of such a thickness that its weight would not deprive the aircraft of good maneuverability and flying performance and, on the other hand, it was necessary that the armor should protect the aircraft against concentrated enemy small arms fire, i.e., make the aircraft invincible to fire from rifles, machine guns and partially invincible to small caliber guns.

During the initial design stage, they analyzed the possible Direction of small arms and machine gun fire from the ground to the aircraft, the most vulnerable spots in the airframe and the firing angle of impact with the armor surface and they selected an individualized plan for armor plating with sheets of various thicknesses; the external surfaces of the sheets were given a streamlined shape. Transparent, 55-mm thick armor was used for the cockpit canopy and 12-mm thick armored plates were partially used above and behind it.

The offensive weapons system consisted of two 20-mm cannons (120 rounds), two 7.62-mm machine guns (1,500 rounds), 8 rockets and a 400-600 kg bomb load. At that time, no other tactical aircraft in the world had such a weapons system.

The defensive systems were the armored hull and the upper gun mount for protection against fighter attacks from the rear.

The aircraft's powerful weapons and armament inspired confidence in its superiority over the enemy and in its safety. Indeed, even during forced landings in the woods in IL-2's, the pilots, as a rule, were not hurt in the armored cockpit.

The aircraft's superior tactical performance made it possible for the pilots who were experts in ground attack strikes to achieve a great deal of effectiveness in combat operations. Thus, during his 48 combat sorties in an IL-2, Lt K. P. Korobeynikov knocked out 17 tanks, destroyed 50 motor vehicles and set 3 fuel tanks on fire. Our aircraft destroyed half the tanks which broke through to Moscow. From 22 November through 22 December 1941 alone, our aircraft put approximately 600 tanks and 5,000 motor vehicles with military cargo out of commission and they destroyed a large number of enemy EM and officers. Besides inflicting material losses on the enemy, ground attack aviation had a demoralizing effect on his forces. It was not by accident that the fascist German soldiers called the IL-2 ground attack aircraft the "black death."

The front line pilots held the IL-2's combat performance in high esteem and they expressed the desire that it be further improved. Their desires boiled down to the following.

First, increase the fire power of the cannons and rockets for more effective destruction of enemy tanks, armored personnel carriers and self-propelled artillery pieces. In response to this, S. V. Il'yushin's Experimental Design Bureau began working on the installation of new, more powerful 23-mm cannons designed by A. A. Volkov and S. N. Yartsev (the VYA-23) on the IL-2.

Second, increase the capacity of the AM-38 engine to enhance the aircraft's maneuverability over the target and to reduce its take-off run from natural surface strips. Because of this suggestion, A. A. Mikulin's Experimental Design Bureau began to develop an augmented version of the AM-38 engine (the AM-38F engine with a take-off rating of 1,750 hp.). During the augmentation, the compression ratio was reduced (from 6.8 to 6.0) and this made it possible to use more widely employed aviation fuel. At the same time, the altitude was reduced from 1,650 to 750 m since combat experience showed that the IL-2 primarily operated at low altitudes. In addition, the operational reliability of the AM-38F engine was significantly improved.

The IL-2, with its enhanced armament and augmented AM-38F engine, successfully passed the State Tests and, in the third quarter of 1942, plants began series production of these aircraft.

A gunner's compartment and a machine gun were installed to repel fighter attacks from the rear hemisphere. Trailing edge flap deflection on take-off was introduced for the first time to reduce the aircraft's take-off roll. In spite of the aircraft's increased weight due to the installation of the more powerful cannons and the gunner's compartment with the large caliber machine gun, this made it possible (along with the take-off rating of the augmented AM-38F engine) to reduce the take-off roll by approximately one-third as compared to the previously produced single-seat IL-2's with the AM-38 engine. Fiber-protected gas tanks were put into series production. They prevented fuel leaks when the tanks were hit by standard and large caliber bullets and 20-mm armor piercing shells.

The series-produced two-seat IL-2's first participated in combat on 30 October 1942 near Stalingrad as part of the Stalingrad Front's 3rd Air Army.

Due to a number of measures taken by S. V. Il'yushin, in conjunction with other experimental design bureaus and scientific research institutes, the protection against enemy fire and the primary weapons systems were improved. For their outstanding success in developing aircraft which were adopted for service, S. V. Il'yushin's Experimental Design Bureau was awarded the Order of Lenin on 5 September 1942.

Due to the sharply increased production of IL-2's, new aircraft armor, the AB-2, was developed. For the same bullet-proof characteristics, this armor contained twice as little nickel and three times less molybdenum than the AB-1 which had been used previously. Scientists, metallurgists, production engineers and industrial workers ensured the production of about 46 armored hulls per day. At the aircraft plants, the production of the IL-2's primary units and the assembly of the aircraft were changed to flow lines and the labor intensiveness for manufacturing individual units, assemblies and parts was reduced. As a result, the labor intensiveness for producing a single aircraft decreased by 37.9 percent during a single year (from 1942 through 1943).

The front began to receive the improved ground attack aircraft in ever increasing numbers. In accordance with their combat employment experience, the tactics for ground attack aircraft combat operations were changed. At the beginning of the war, the ground attack aircraft operated, as a rule, in small formations at low altitude and hit the enemy with machine gun fire, cannon fire, rockets, bombs and incendiary projectiles. During the war, there was an increase in the density of anti-aircraft artillery cover for enemy combat formations throughout the tactical depth of his defense. All types of standard and large-caliber (up to 15 mm) automatic small arms and primarily small caliber anti-aircraft artillery (from 20 to 57 mm) were used against the IL-2. The IL-2's began to operate at altitudes which reduced the effectiveness of automatic small arms and small-caliber anti-aircraft artillery.

With these operational tactics against ground-based targets, the role of the IL-2's bombing equipment increased. A special order for the Air Force required that the IL-2 be used to destroy the enemy's defensive concrete pillboxes using HE bombs. In carrying out this order, many ground attack aviation regiments began to accomplish their combat sorties in the IL-2 with 400-600 kg bomb loads and with eight rockets suspended on the aircraft at the same time.

Essentially, in the summer of 1942, the IL-2 ground attack aircraft became the main strike force of our Air Force's tactical aviation; they were multi-role ground attack aircraft and short-range, daylight bombers.

They were assigned this role not simply because there was a small number of daylight bombers. A different reason was the decisive factor in this selection: under the adverse winter weather conditions, the ground attack aircraft were the ones who could provide the greatest assistance to the advancing forces. They were less dependent on the vagaries of the weather than the bombers were; it would be easier to search out and prepare new airfields for them. The IL aircraft were based closer to the front lines and were easier to service; this made it possible to use them with greater intensity. Finally, these aircraft, armed with bombs and rockets, had powerful airborne weapons systems and were irreplaceable in supporting ground forces. The Air Force Headquarters did everything possible to maximize the air armies' ground attack aircraft strength.

During the Great Patriotic War, the ground attack aircraft also had another role. In February 1942, a German army was encircled near Demyansk. The German headquarters set up a supply by air for the encircled group. The pilots of the 33rd Guards Ground Attack Air Regiment used the IL-2's for the first time to counter the Junkers-52 transports (load-carrying capacity of 2 tons or 15 soldiers with weapons).

Pilots Galin, Oleynik, Nesterov and Frolov each shot down three Junkers-52 and JrLt Zhigarin shot down three enemy aircraft and destroyed seven on the ground during a single sortie.

Hero of the Soviet Union MSgt V. Ya. Ryaboshapka of the 299th Ground Attack Air Regiment was one of the first to shoot down an enemy fighter in an IL-2. While carrying out their primary missions in the summer and fall of 1942, ground attack aircraft shot down 44 enemy aircraft "in passing" on the Northwestern Front alone. At that time, the ground attack aircraft began to be used on a widespread basis to engage the enemy's transports and bombers in the air. Based on a special decision of the State Defense Committee, a modified, single-seat IL-2 prototype (a fighter bomber) was built in 1943 and a single-seat IL-1 ground attack fighter prototype was built in 1944.

Aircraft manufacturers continued to improve the ground attack aircraft. In 1941-1942, a new 37-mm aircraft cannon designed by N. E. Nudel'man was tested and accepted for service. In 1943, two of these cannons were installed on the IL-2 in place of the 23-mm cannons. Tests showed that the IL-2 ground attack aircraft had received a new, powerful weapons system whose shells penetrated the hull roof plates of all the enemy's tanks and self-propelled artillery pieces as well as the armor on armored personnel carriers and armored vehicles and partially penetrated the side and rear armor of tanks and self-propelled artillery pieces. The newspaper KRASNAYA ZVEZDA wrote about this: "Our Il'yushin-2 ground attack aircraft with their large caliber cannons can destroy all the enemy's primary tanks. It is most advantageous for the pilots to attack the tank from the side or from the rear, from a dive, at an angle less than 30 degrees... Under any firing conditions, armored vehicles and armored personnel carriers equipped with 10-14 mm armor can easily be destroyed by cannon fire."*

At the same time, in July 1943, the HCAB-2.5-1.5 hollow charge anti-tank bombs (the size of the bomb corresponds to a weight of 2.5 kg with an actual weight of 1.5 kg) were dropped by IL-2 aircraft for the first time. With a sufficiently dense drop, the distance between bomb impact points was small (1-2 m). When a stick of bombs was dropped on tanks or an armored column destruction was inevitable. Bombing was conducted from medium (600-800 m) altitude in level flight. On the first day these bombs were used, 70 enemy tanks were destroyed.

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*N. Shaurov, "Aircraft Against Tanks," KRASNAYA ZVEZDA, 8 July 1943.

During 1943, A. A. Mikulin's Experimental Design Bureau was working on a design for a new, powerful aircraft engine, the AM-42 (take-off rating of 2,000 hp), which was installed on the heavy, two-seat IL-8 ground attack bomber prototype (take-off weight of 7,260 kg with a 1,000 bomb load) in 1943.

The successful employment of the IL-2 as a tactical bomber which used various sizes of bombs led to the idea of developing the larger IL-8 ground attack aircraft which was distinguished by its greater bomb load.

Also in 1943, S. V. Il'yushin's group developed a design for the new IL-10 ground attack aircraft with the AM-42 engine; the basic idea for this aircraft did not consist of a modification of the IL-2 ground attack aircraft but rather consisted of developing a new aircraft with significantly better maneuverability, a 30 percent greater speed than the IL-2, reinforced armor protection and a more powerful weapons system with the same standard take-off weight. The IL-10 was to be the personification of the large amount of experience obtained from the combat employment of the IL-2 in 1941.

When the turning point was taking place during the second period of the war, our tactical fighter aviation had achieved air superiority over the enemy's air force in sustained combat. Losses of ground attack aircraft to enemy fighters were reduced. At the same time, there was a significant increase in the numbers, and most importantly, in the caliber of the fascist German forces ground-based air defense weapons. For this reason, the new ground attack aircraft was to have enhanced maneuverability and speed to reduce its vulnerability to enemy ground force air defense systems.

As a result of the extensive scientific design work which was jointly conducted by the CAHI* and S. V. Il'yushin's group, a two-fold reduction in the IL-10's aerodynamic drag was achieved as compared to the IL-2. In spite of the significant reduction in the area of the wing due to the enhanced aerodynamic features of the airfoil and the more effective high-lift landing devices, the landing speed was actually the same. This was achieved by using a new arrangement for installing the water and oil coolers, by eliminating the undercarriage housing, by introducing a skid retraction system, by using solid, uninterrupted flaps under the fuselage, by reducing the maximum cross-section of the fuselage and by reducing the wing area. The SH-20 20-mm cannon designed by B. G. Shpital'nyy was installed in the gunner's compartment.

* CAHI[Central Institute of Aerohydrodynamics]

The IL-10 prototype was built in April 1944 and it passed the State Tests with high marks in June of the same year. The tests were conducted by military test pilot A. K. Dolgov who conducted the State Tests of the IL-2 ground attack aircraft in 1941. The IL-10's advantages over the IL-2 were so great and obvious that the State Defense Committee's decision of 23 August 1944 committed the People's Commissariat for the Aviation Industry to produce 100 IL-10's at two plants by the end of the year. In October 1944, the first IL-10's began to enter service with the tactical aviation ground attack air regiments. On 2 February 1945, operational trials of a large group of new ground attack aircraft began on the front along the Neisse River (near Sproettau and Oberhermsdorf) in Germany. From the results ofthe State Tests and the operational trials of the IL-10, it was found that the new ground attack aircraft had the following advantages compared to the IL-2:

--the higher speed (120-145 km/hr), the greater range of speeds and better maneuverability made combat maneuvers in the target area easier and, in a number of cases, made it possible to engage in aggressive air combat with enemy aircraft;

--the more complete armor plating, including the gunner's compartment, and the more powerful defensive weapons system increased the aircraft's survivability in combat;

--the aircraft's enhanced stability and controllability (especially when compared to the IL-2) as well as the simplicity of pilot procedures made it easier for the flying and technical personnel of ground attack aviation to transition to the IL-10.

With practically the same armor plating scheme as the IL-2, the IL-10 was significantly less vulnerable to the enemy's automatic small caliber anti-aircraft artillery and fighter aircraft due to its greater speed and enhanced maneuverability.

For developing the new ground attack aircraft, S. V. Il'yushin's Experimental Design Bureau was decorated with the Order of the Red Banner on 2 November 1944. Also in 1944, S. V. Il'yushin's design bureau group developed the IL-16 light ground attack fighter based on the IL-10.

The average daily production of IL-2 ground attack aircraft (in 1944, together with the IL-10 and, in 1945, together with the IL-10 and IL-16) increased from 1.3 aircraft in the first 6 months of 1941 and 7 in the second half of 1941 to 20 aircraft in 1944 and 40 aircraft in 1943-1945.

The armored ground attack aircraft became the primary strike force of our tactical aviation; they usually operated at a depth of about 250 km from their home bases against land and sea targets.

They became the Air Force's primary aricraft for close support of ground forces and for operations in the tactical depth, and partially in the operational depth, of the enemy's defense.

During the war, German aircraft designers attempted but were unable to develop a ground attack aircraft. In 1942, a special purpose organization--the Ground Attack Aircraft Inspectorate of the Air Force Ministry--was established in Germany; its mission was to develop ground attack aviation. However, it was not able to accomplish this mission. The armored, ground attack modifications to the Focke-Wulf G-190 fighters were heavy, short on maneuverability and had a small bomb load.

The twin engine Henschel-129 ground attack aircraft, with its armored cockpit, partially armored engines and single large-caliber cannon, was inferior to the IL-2 in combat performance and was produced in very small numbers during the war.

During the war, the British and U.S. Air Forces used modifications of the standard Hawker fighters as ground attack aircraft: the Hurricane and Typhoon, the Curtis P-40, the North American P-51 and the Republic P-47; they were not armored and had a small bomb load. These aircraft were only able to accomplish the mission of close air support for their ground forces at a low level of effectiveness when enemy air defense was slight or suppressed.

CHAPTER 9

TOUCHING UP A CREATIVE PORTRAIT OF THE DESIGNER-GENERAL

ColGen A. N. Ponomarev, doctor of engineering sciences and State Prize Winner

It is impossible to imagine domestic ground attack aviation during the Great Patriotic War without the IL-2. No other aircraft would have been produced in such numbers; there is no such number of twice-honored Heroes of the Soviet Union who would have won this title in any other type of aircraft. Of the 47 airmen who hold the Order of Glory, 1st degree, 36 were ground attack aviation gunners.

The development of the IL-2 ground attack aircraft was a remarkable tactical development. The combination of an effective firing capability and armor, of simplicity and error-free operation in combat employment brought this aircraft its well-deserved fame. The good news which arrived from the front lines about the military feats of the ground attack aircraft inspired the designer of the "flying tank" to improve the aircraft; its heirs were the IL-10the IL-16 and the IL-20. The IL-4, which was developed as a long-range bomber, stood in the same rank with them.

The omnious war years were rumbling and we had talked to Sergey Vladimirovich on numerous occasions about fundamentally new power plants for modern aircraft and ways for developing aviation.

There was a great deal that was unknown and unexplored. I have an especially vivid memory of the first flight of the bomber developed by Sergey Vladimirovich; a powerful turbo-jet engine designed by A. M. Lyul'ka was installed on it. It is hard to imagine that it was just a quarter of a century ago, in July 1947, that this jet aircraft was launched--the predecessor of modern bomber aircraft. I remember our excitement while we awaited the results of this flight. Just the report from

Vladimir Kokkinaki--"I feel as comfortable as in the flight laboratory"--calmed us down and inspired confidence in the possibility of developing aircraft with fundamentally new power plants.

Time passed and a requirement arose to equip domestic aviation with jet bombers. There was a lot of discussion on what the aircraft's maximum bomb load, speed and range should be. The issue of the feasibility of installing defensive weapons systems on it was raised especially sharply (to increase aircraft speed, certain foreign companies had left defensive weapons off it).

The assignment was given to several design bureaus. Aircraft were built and the IL-28 was introduced into the inventory. Like all the aircraft from S. V. Il'yushin's design bureau, the IL-28 was built in large numbers and was truly a "workhorse" of domestic bomber aviation. Many generations of bomber pilots, navigators and gunners-radio operators were trained on it and flew it.

In addition to the military aircraft they designed, S. V. Il'yushin's design bureau developed numerous airliners for domestic civil aviation and for the airlines of the socialist countries in the postwar period. This was especially important since the civilian aircraft fleet was small and obsolete after the Great Patriotic War. There was a felt need for an airliner which would be easy to land and take-off, reliable in flight and comfortable. This aircraft should also combine flight safety and economy. At first, this aircraft was the twin-piston, radial air-cooled engined IL-12; later it was the IL-14 which opened an entire epoch in the postwar production of airliners.

Sergey Vladimirovich devoted a great deal of persistent effort and attention to the development and improvement of this aircraft; he personally participated in the flight tests. He frequently made long flights along the most remote routes along with his chief pilot, V. Kokkinaki, twice-honored Hero of the Soviet Union. This aircraft has not only carried passengers in our country but also in the countries of the socialist community where it has also been in series production.

Our domestic Civil Air Fleet now had a requirement for a modern airliner. The mission of designing such an aircraft was assigned to S. V. Il'yushin's design bureau. And, the IL-18 appeared in the skies. A large number of technologically difficult problems had to be resolved during the design of this aircraft. For example, the development of a pressurized cabin, which does not come as a surprise to anybody now. It is hard to imagine that at one time this was a difficult problem, not only due to pressurization but also to cooling the air to maintain normal life-support conditions at an altitude of 7-8 km. Numerous "bugs" were eliminated during this aircraft's operational use. Thus, for example, when the aircraft had already been built and was being used, work was conducted to counter the noise and vibrations in the passenger cabin. As the saying sometimes goes, it "grew up" and was gradually transformed into an aircraft which accommodated 110 passengers and could fly to other continents. The design bureau's work in developing this aircraft was highly appreciated. In 1960, S. V. Il'yushin and a group of his co-workers were awarded the Lenin Prize.

It is obvious that simply making a successful selection of a power plant is clearly not enough to develop a modern airliner. A fundamentally different aircraft configuration was required, one which would make it possible to significantly reduce the level of noise and vibrations in the passenger and crew cabins. In the new IL-62 (186 passengers and a range exceeding 9,000 km), it was decided to get rid of the engines suspended under the wing and move them to both sides of the fuselage's tail section. Numerous versions of this aircraft configuration were studied at the design bureau, since it was necessary to compensate for the negative effect of the large weight located in the aircraft's tail section on its center of gravity. The increased size and location of this aircraft's tail unit were also unconventional. All of this required a lot of preliminary estimates, wind tunnel tests and endurance and strength tests.

In 1965, the IL-62 attracted universal attention at the Paris Aerospace Show where visitors admired this ship and specialists discussed the qualities of this remarkable Soviet airliner, which earned flattering reports from them for its graceful aerodynamic shape, lack of noise in flight and good take-off and landing performance.

The IL-62 demonstrated all its indisputable merits at the Domodedovo Air Show on 9 July 1967. After landing in front of the stands, the aircraft not only demonstrated its forward movement but also "reverse." I remember the following episode. During its first "guest" flight to the United States, the IL-62 landed at New York's Kennedy Airport after spending an hour in the "holding pattern." Dozens of reporters with diverse photographic, movie, radio and television equipment surrounded the aircraft. The aircraft was evaluated according to its merits in the American press. There was an amusing incident when the aircraft left for home. The passengers and crew took their seats in the aircraft, which was standing with its nose close to the airport building and was connected to it by a covered ramp. A small tractor approached the aircraft to tow it to the runway; but, the vehicle did not reach our aircraft. To the surprise of those present, the aircraft commander requested that the vehicle move aside. He started engines, switched on the reverse thrust (reverse), put it in "reverse" and reached the runway under his own power.

Designer-General A. I. Mikoyan said that Il'yushin was "an entire era in postwar civilian aircraft production, an era which included all the modern qualities of aircraft: speed, altitude, design simplicity, operational reliability and comfort." A member of an airfield crew and a colonel-general, a designer of gliders and intercontinental airliners, officer-in-charge of the Caucasus Front aviation train during the Civil War and manager of a design bureau, a full member of the USSR Academy of Sciences, Lenin and State Prize Winner, thrice-honored Hero of Socialist Labor and USSR Supreme Soviet Deputy--this is the record of this remarkable man's life.

In the IL-2 and IL-4, our pilots routed the fascist hordes and their hardware. The IL-28 and IL-54 were an era in domestic jet bomber aviation. The IL-14, IL-18 and IL-62 were our civil aviation's beginning, development and mastery of not only our air space but also of trans-Atlantic air space.

CHAPTER 10

CIVIL AVIATION AIRCRAFT DESIGNED BY S. V. IL'YUSHIN

R. V. Sakach, doctor of engineering sciences and
N. V. Shklyarov

The Great Patriotic War was coming to a victorious climax. The fascist German invaders were being rolled back under the pressure of the Soviet Armed Forces. Our pilots were not giving the enemy a chance to raise his head. The IL-2 and IL-10 ground attack aircraft were annihilating the enemy's men and equipment. The guns were still thundering and the tanks were still executing swift attacks and the Soviet people had already begun to lay a firm foundation for the transition of the country's economy to a peacetime basis; this transition would ensure the swift reconstitution of all sectors of the national economy.

With his inherent farsightedness, S. V. Il'yushin was the first aircraft designer to understand the need to develop a modern airliner which would replace the small fleet of aircraft which was being used by Aeroflot at that time; based on their flying performance and technical specifications, these aircraft were obsolescent.

So, in 1943, while continuing its work on military aircraft, the Experimental Design Bureau, under S. V. Il'yushin's management, began its work on developing the first IL-12 airliner. And here is what was remarkable about that: they began designing this aircraft without any technical requirements having been submitted for it; it was entirely at Il'yushin's initiative; he was able to manage and inspire his group in such a manner that an unofficial prototype committee had already been set up in 1944. The Civil Air Fleet representatives on the committee submitted proposals which were subsequently successfully implemented by the Experimental Design Bureau.

Now that more than 30 years have passed and it has become a normal occurrence to travel on a modern airliner where everything has been anticipated to maximize flight safety and comfort, it is difficult to imagine the number of issues and problems which faced the Experimental Design Bureau Group while they were developing the IL-12.

The Civil Air Fleet employees also faced a number of snags; they had to prepare and document their proposals on a number of issues which arose during the developmental process for the aircraft; they also had to prepare for the aircraft's flight testing and future operational use. It was at that time that the creative cooperation between the employees of the Experimental Design Bureau and Civil Air Fleet arose; this cooperation has facilitated solutions to all the complicated problems of developing and commissioning IL aircraft right down to the present. Within a short period of time, an IL-12 prototype was designed and developed. After brief plant tests, the IL-12 was accepted for State Tests on 1 June 1946. This day should be considered the beginning of the IL airliner era in civil aviation.

The prototype underwent State Tests for 2 1/2 months. A large number of flights were conducted at the normal take-off weight of 16,380 kg; then, at the commission's recommendation, the take-off weight was increased to 17,000-17,500 kg. The IL-12 successfully passed the State Tests. Its performance exceeded the performance of the C-47 (DC-3) and LI-2 which were in operational service. Actually, the IL-12 had good specifications and economy for that time (see the Appendix, the section on "Basic Specifications for Aircraft Designed by S. V. Il'yushin").

Based on an order from the Civil Air Fleet at the end of 1946, the IL-12 was put into series production and subsequently became the cradle for many generations of IL aircraft. Operational testing of five IL-12's was conducted by the Civil Aviation Scientific Research Institute at the facilities of the Civil Air Fleet's 1st Air Group at Vnukovo Airport. On 1 May, 1947, a formation of IL-12's was already participating in the fly-by in Moscow. During the operational testing, 52 aircraft captains flew the airplane. According to their overall evaluation, the IL-12 had good handling characteristics, was easy to control and was completely within the flying capabilities of not just first-class pilots but also second-class pilots.

Despite the universal recognition and successful operational use of the IL-12, S. V. Il'yushin and the Experimental Design Bureau's designers did not rest on their laurels; they continued their work on further improvements to the aircraft and, in 1950, this had already led to the development of a modification to it--the IL-14; this aircraft incorporated all the best plans of the designers at that time, plans which were primarily directed at flight safety. The more reliable and economical ASH-82T engines and the AV-50 propellers with improved aerodynamics were installed on the IL-14; directional stability and controllability were improved in the event of an engine failure; the time was reduced for feathering a propeller; the effectiveness of anti-icing devices was improved; and a number of other improvments were made, including passenger cabin decorations and enhanced comfort. Maintenance was also simplified and the air frame service life and systems service life were increased.

Jumping ahead, it is possible to state that the correctness of the ideas incorporated in the IL-14 and the efficiency of its design solutions have withstood the test of time. And now, more than 20 years later, various modifications of the IL-14--which are recognized by flying personnel and passengers for their superior safety and reliability--are frequently encountered, especially in the eastern and northern regions of our country.

During the State Tests of the IL-14P, more than 150 flights were conducted with a total flying time of 250 hr.

During the operational testing of this aircraft at natural surface and paved airfields, flights were conducted on an extremely intensive basis, reaching 8-9.5 hr of flying time on individual days; this exceeded the flying time for the IL-12 by a factor of 2-3. During four days of flying, the aircraft made a round-trip flight from Moscow to Khabarovsk without any equipment malfunctions.

As already noted above, a lot of modifications and improvements were implemented on the IL-14; the requirement for these changes was discovered while the IL-12 was being used and flight tested. One of these changes should be discussed since it not only provides a marvelous characterization of the spirit of mutual cooperation which had already developed at that time between the employees of the Experimental Design Bureau and Civil Aviation, but it also represents a specific stage in the job of up-dating IL aircraft. As a result of the large volume of work conducted by the Civil Air Fleet's Scientific Research Institute, with the direct participation of the employees of the Experimental Design Bureau, to establish procedures for flying the IL-2 in case an engine failed during take-off, it was discovered that the aircraft's rate of climb with gear extended in the continued take-off regime with one engine operating was not sufficient. This lead to certain restrictions on take-off weight and it somewhat limited the possibility of using existing Civil Air Fleet airfields.

To reduce the parasitic drag, Engr M. V. Lipatov suggested that the main gear well be covered with flaps when the gear was extended. (An experiment was conducted on the IL-12 at Ashkhabad Airport in August 1948 by test pilot A. I. Voskanov.) This made it possible to increase the forward speed by more than 30 km/hr with two engines functioning and, most importantly, it made it possible to increase the IL-12's vertical velocity on one engine by approximately 40 percent. The results of this experiment were implemented for the first time in the USSR on the IL-14 airliner. At that time, this design solution did not exist on foreign airliners.

The swift growth of passenger transportation in those years necessitated the appearance of new aircraft with greater passenger capacity. In September 1956, the TU-104 turbo-jet airliner appeared for the first time on Civil Air Fleet routes.

At the same time, S. V. Il'yushin's Experimental Design Bureau was completing its work on developing one of the first turbo-prop airliners in our country, the IL-18.

To optimize the power plant, IL-18's were built with NK-4 and AI-20 engines. The IL-18 underwent State Tests and operational testing with both types of engines. There were cases of engine compressor disintegration during the tests of the IL-18's with the NK-4 engines. Because of this, S. V. Il'yushin, in conjunction with the operational testing commission, made the decision to continue these tests and to only put the IL-18 with AI-20 engines into series production.

The State Tests of the IL-18 were conducted within a compressed time frame. The IL-18's operational testing was conducted from January 1958 through April 1959. During this time, the total flying time for all the aircraft was greater than 5,000 flying hours. Simultaneously with the operational testing, checkout tests of the IL-18 (with both the NK-4 engines and the AI-20 engines) were conducted to identify special features in the flying performance of these aircraft under realistic conditions.

Upon completing the entire package of tests for the IL-18, the operational testing commission, with Designer-General S. V. Il'yushin's participation, made the decision to begin passenger service on 20 April 1959.

That year, the IL-18 carried out flights to several foreign countries, including African countries.

All the subsequent work by Il'yushin and his group to up-date the IL-18 provided this aircraft with the opportunity of becoming one of the most economical and large-volume aircraft in civil aviation. Operational experience, especially on foreign routes, showed that it was necessary to have IL-18's with greater range to carry out these flights. While the Experimental Design Bureau had successfully guaranteed greater range for individual flights previously by installing additional fuel tanks in the fuselage (for example, this is what they did in 1961 to support a scheduled range of 7,000 km for the flights to the Antarctic), the further expansion in foreign contacts required the development of special modifications to the IL-18. So, in 1965, the Civil Air Fleet Scientific Research Institute began to test the IL-18D with a 33 percent increase in its operational range compared to the normal IL-18; this significantly expanded the opportunities for using this aircraft.

Simultaneously with their up-dates and new modifications to the IL-18,which primarily operated on Civil Air Fleet medium-range trunk routes, the Experimental Design Bureau group led by S. V. Il'yushin was intensifying its work to develop the IL-62 long-range trunk route aircraft in 1960. This long-range, turbo-jet, high-speed aircraft would replace the TU-114.

During 1966, the Experimental Design Bureau completed the plant tests and development of the IL-62 prototype with four NK-8-3 turbo-jet engines designed by N. D. Kuznetsov.

The State Tests were successfully conducted over a four-month period; by the time these tests were completed, the extent of all types of testing, including plant and developmental tests, was more than 1,200 hr while the scope of operational testing was over 2,000 hr.

As a result of the successful completion of this work, the IL-62 began its passenger service: on 8 September, on the Moscow-Khabarovsk route and,on 15 September, on the Moscow-Montreal route. This was the first time that scheduled operational use of a new type of aircraft in Aeroflot was begun simultaneously on domestic and international routes. In this case, the complete confidence in the reliability of the new, high-speed airliner which became Aeorflot's flagship, had an effect.

Designer-General S. V. Il'yushin and his group continued their work to up-date the IL-62. First of all, in 1968, an IL-62 with the more economical, enhanced thrust NK-8-4 engines was submitted for State Tests. Moreover, the aerodynamics of the engine nacelles had been improved. As a result of this, the range was increased by approximately 300-500 km and the maximum take-off weight was increased from 160 to 161.6 tons. In turn, this somewhat increased the aircraft's economy.

During subsequent work to improve the IL-62, the modified IL-62M, with turbo-fan engines designed by P. A. Solov'yev, was developed. With their increased thrust, the more economical D-30Ku engines made it possible to increase the aircraft's range and improve its economy; a number of structural innovations improved the lateral controllability in the take-off and landing configuration and reduced the approach speed somewhat.

If you look at an aircraft schedule for domestic trunk routes, you can see that, throughout their many years of operational use, the IL aircraft have occupied and continue to occupy one of the top places on the list.

The IL-62 long-range trunk route aircraft and the IL-62M modification to it are accomplishing the majority of the air transportation on the international routes which link Moscow with 78 of the world's countries. These aircraft fly to countries in all the world's continents. This large-volume utilization and general recognition of the airliners developed by S. V. Il'yushin's Experimental Design Bureau is not accidental. Besides ensuring a high degree of safety, reliability and comfort for flights on IL aircraft, the economic and operational efficiency are of considerable importance to civil aviation as a commercial organization.

The transportation cost for the IL-18 is the lowest in comparison to the other types of aircraft presently in operational service. It is 30 percent lower than the average ton per kilometer cost for Aeroflot. The economic efficiency of a passenger (transport) aircraft's design can be judged by the fact that a simple 1 percent reduction in operational expenses makes it possible to save over 15 million rubles per year.

The high technical and economic statistics for aircraft developed by S. V. Il'yushin's Experimental Design Bureau were primarily obtained from their superior aerodynamic efficiency and high standards for planning weight; for this reason, these aircraft have always met the world state of the art. A great deal of the credit for this goes to Sergey Vladimirovich's closest assistants: D. V. Leshchiner, V. M. Sheynin, N. P. Stolbovoy, G. G. Murav'yev and others.

The operational reliability of individual systems and structural elements was not just achieved as a result of thoroughly planning and developing them but also by considering the operational experience with their previous counterparts; Sergey Vladimirovich had a very serious attitude about this.

It can be asserted that S. V. Il'yushin's Experimental Design Bureau has its own special work style, which is primarily characterized by the fact that the design bureau only releases items for operational use which have the employee's absolute confidence and only when they are convinced that it cannot be done better at this stage.

I would like to use several examples to show how the Experimental Design Bureau group solved invidivual problems which were directly related to ensuring a high degree of regularity and safety for flights under adverse weather conditions and also those problems linked to putting the finishing touches on the interior of passenger cabins. The solution to the first of these problems, the most difficult ones, was specifically related to automating aircraft control during one of the most difficult stages of flight--the landing approach--and to protecting the aircraft against icing.

It can be presumed that serious work on automating the landing approach for civilian aircraft got underway in 1959 when a flying test-bed was developed on the IL-14 according to Il'yushin's instructions; it was equipped with the Put' flight-director approach system. This system was developed and introduced with the active participation of Experimental Design Bureau employees A. A. Maslennikov, G. S. Krivoruchenko and P. I. Babayev and Aeroflot employees S. L. Belgorodskiy and S. A. Stepankovskiy.

The flight tests conducted on this aircraft made it possible to determine the basic directions for resolving the complex problem of automating approach control. A year later, the Put'-1 and then the Put'-1M systems were developed on the IL-18. For a number of years, they made it possible to accomplish flight director approaches with the SP-50 course and glide path beacons.

The widespread introduction of IL-18's equipped with flight-director systems into operational use stimulated the development of work not only in developing and improving the systems but also in the area of fundamental improvements to electronic landing support equipment, airfield equipment and crew training.

The IL-18 is the first domestic aircraft for which the automatic approach system based on the Put' flight-director system and the AP-6E autopilot was developed. This laid the foundation for solving the problem of ensuring flight safety: automatic trim tab systems were developed; special warning equipment was built; and other work was accomplished. As a result, the BSU-3P airborne automatic control system appeared; at present, not only the basic fleet of IL-18's but also a number of other Civil Air Fleet aircraft are equipped with this system.

The BSU-3P-equipped IL-18's were the first domestic aircraft to be certified for landing under Category I landing minimums (decision height--60 m, runway visibility--800 m). The routes serviced by these aircraft have a 5-8 percent increase in the regularity of service; this is an extremely important achievement.

The work on the Polet theme played an important role in developing a comprehensive, flight control and navigation system for heavy airliners; a special-purpose IL-18, which served as a flying test-bed, was equipped to carry out this program.

This work made it possible to sharply reduce the time period for developing and introducing fundamentally new automatic flight control systems for large airliners. The SAU system installed on the IL-62's was the first domestic back-up system with the enhanced reliability and safety required for operational use in Category II and III landing minimums. It was supplemented by experimental equipment which made it possible to accomplish automatic touchdowns in the IL-62's.

While analyzing the course of domestic civil aviation development, it should be mentioned that the aircraft developed under the leadership of S. V. Il'yushin differed from other airliners in their high degree of automated flight control, the development of which guaranteed enhanced flying safety and regularity.

In contrast to many aircraft which were equipped with de-icer boots at that time, the IL-12 had a more effective hot air anti-icing system to protect the wings and tail section; this gave it obvious advantages over other types of aircraft. During one of the test flights conducted in Leningrad, a scheduled LI-2 made a forced landing due to severe icing while climbing. The aircraft anti-icing system was not able to handle the icing and the crew was forced to abort the flight and use maximum engine power to land. Under these same conditions, an IL-2 safely carried out its flight in accordance with its test program.

The IL-14 had an extremely powerful anti-icing system for those times. A team of experienced design bureau specialists, made up of B. V. Pavlovskiy, B. Ya. Kapliyenko and others, worked on the development of this system. Sergey Vladimirovich personally supervised the design of this system. A hot air anti-icing system which used the heat from the engine exhaust was employed to protect the wings and tail section. The IL-14's anti-icing system was a significant step forward in effectiveness and economy.

When the IL-18 was being designed, the task arose to ensure safe operations under any weather conditions, including the most severe icing conditions. The Experimental Design Bureau specialists decided to use a cyclical electrical de-icing system on the aircraft's wings and tail section. Civil Aviation Scientific Research Institute personnel suggested that this system be supplemented with so-called heated strips; the purpose of these strips was to continually heat a narrow area along the leading edge and cut the ice which built up on the leading edge of the wing or tail section into two parts which would then be easily discarded when the cyclical heater was turned on.

In spite of the large amount of data which testified to the superior effectiveness of the "strip" system, it had a lot of opponents since its design and production presented significant difficulties. Arguments and discussions began. This is where Sergey Vladimirovich displayed his inherent, remarkable ability to correctly perceive something new and find an optimal solution. During one of the conferences, Sergey Vladimirovich listened to the proponents and opponents of this proposal and then, as usual, quietly stated: "It seems to me that this suggestion is reasonable; we should make it and test it." So, the "strip" anti-icing system was made and installed on the stablizer of an IL-18.

A distinguishing feature of Sergey Vladimirovich's group was its ability to achieve a lot with relatively little effort. An example of this was the design of an anti-icing system for the IL-18's tail section. Several versions of the system were made and tried within a short period of time; they were tested under the most severe icing conditions. A recommendation was made to introduce the most successful system.

Sergey Vladimirovich devoted special attention to developing a highly effective anti-icing system for the IL-62; extremely strict engineering requirements for protection against icing were levied on this system. These requirements were satisfied.

For the first time, a powerful, cyclical hot air anti-icing system was installed on this aircraft. Its distinguishing feature was the combination of an effective ice blow-off and an economical utilization of the hot air drawn from the engines. Plans for the system under development were already submitted during the prototype commission phase. The aircraft was equipped with the highly sensitive SO-2 IL icing detector which was designed by specialists of the Experimental Design Bureau and the Civil Air Fleet Scientific Research Institute. The flight test results showed that this system was as good as the best foreign models of that time in its effectiveness.

Il'yushin took an attentive and serious attitude toward the issues of passenger cabin comfort. The first IL-12 arrived for its testing with an interior which was significantly better than the one on the IL-2, even though only materials like percale and enamel paints were being used to decorate cabins at that time. The seatcovers were made of felt. A special feature of this aircraft's interior, as it was incidentally of all the subsequent IL aircraft, was the fact that all the passenger seats in it were designed the same so that there were no artifical divisions among any of the seats which distinguished them from the rest in equipment, location in relation to the direction of flight, etc. When the IL-18 appeared with its powerful turbo-prop engines and when it was discovered that noise and vibration abatement were very complex and would require large expenditures of weight, Sergey Vladimorivich met the desires of flying personnel and stewards head-on and changed the configuration of the passenger cabins by placing the facilities which people didn't visit at all or visited for a short period of time during flight in the most noisy areas. The path from the IL-12 and IL-14 to the IL-18 was long and difficult. But, as in the solution of the other problems, the tradition established by Sergey Vladimirovich, of making maximum use of the experience gained and of solving problems by considering the operators' opinions, had positive results: new, modern decorating, heat proofing and sound proofing materials were developed and appeared in the necessary quantities; a transition was made to paneling as a method for finishing the cabin ceilings and sides; this made it possible to significantly improve and raise the level of commerical aesthetics.

The continual search for contemporary, promising equipment which would bring the conditions of flight closer to the customary comfort of home was reflected in each new type of aircraft and in each modification to it. Special aircraft cradles were installed for the very little passengers. The seats were improved; not only were they harmoniously matched to the interior but they were truly built for the passenger's convenience, both to relax and to make use of the flying time to read or write. It was not by accident that one of the specialized organizations used a seat from an IL aircraft as the standard when it was assigned the task of developing a universal aircraft seat.

While working on the IL aircraft, the Experimental Design Bureau group was continually improving the aircraft maintenance and repair system and organization; Experimental Design Bureau personnel participated in the scientific research work. The recommendations and measures which were developed on the basis of these materials were directed at improving the reliability and fail-safe design of the aircraft, reducing the labor and materiel expended on maintenance and repairs and improving serviceability, maintainability and interchangeability. As a result of this, periodic maintenance for the IL-18 during a five-year period of operational use was increased from 25, 50, 100 and 200 hr flying time (with which the aircraft was transfered to civil aviation) to 50, 200, 600 and 1,200 hr, respectively, with a simultaneous reduction in labor intensiveness for almost all types of maintenance.

Presently, aircraft maintenance periods have been increased significantly and correspond to the best foreign models for similar types in frequency. Work has also been accomplished on increasing aircraft overhaul life and preventive inspection time frames after the overhaul life has reached the half-way point. Due to this, gross labor expenditures on IL-18 maintenance and repairs have dropped significantly in recent years.

The numerous years of experience which were accumulated on the IL-18's reliability and service life have been used widely in solving the same problems for the IL-62.

In the long-range development of civil aviation for 1990-2000, air services will increase manyfold and the performance statistics for air transport, which have been planned based on completely meeting the requirements of our country's population and the needs of the national economy for various types of aircraft operations, will improve. Under these conditions, the achievement of a high level of technical and economic efficiency for airliners and special-purpose cargo aircraft and a further improvement in flight safety and regularity and in economic efficiency and comfort are of enormous importance.

Undoubtedly, the talented Experimental Design Bureau group which Sergey Vladimirovich Il'yushin has headed and trained for a number of years will make an important contribution to the future development of civil aviation as it has successfully done up to the present.

CHAPTER 11

AIRCRAFT DESIGNED BY S. V. IL'YUSHIN

Chief Designer Ya. A. Kutepov, Hero of Socialist Labor and Lenin Prize Winner

The world first learned about S. V. Il'yushin's aircraft in 1936 when test pilot Kokkinaki set a number of world altitude records for flying with a significant load for that time on the Moscow. This was then followed by the record for speed and for long-range flights within the country and to America. This was the Experimental Design Bureau's first aircraft, the CDB-26; the last modification to this aircraft was later called the IL-4.

From the first days of the Great Patriotic War, another aircraft designed by S. V. Il'yushin--the IL-2 armored ground attack aircraft--took part in combat operations. It was a complete surprise to the enemy. The enemy's attempt to build a similar aircraft during the war were not successful. The IL-2 was to remain the only aircraft in this class. It was distinguished by its good flying performance, control simplicity and the exceptionally large firepower of a single salvo. All the aircraft's vital parts--the crew's compartment, the engines, the fuel and oil systems--were enclosed in an armored hull which guaranteed the aircraft's invulnerability.

The development of the IL-2 in 1938 led to the appearance of a new type of combat aircraft--an armored ground attack aircraft--in the inventory of the Soviet Armed Forces; in addition to their powerful machine gun and cannon weapons systems (because of which, they were called "anti-tank aircraft") and their bombing weapons systems, they had from four to eight stations for firing rockets.

The IL-2 ground attack aircraft had good survivability. During the war, Hero of the Soviet Union G. Gofman[1] flew over 150 combat sorties in it. His aircraft took a total of 600 holes during combat. Some of them were serious. At Sevastopol', an anti-aircraft shell hit the fuel tank; but, the designer had anticipated this and the empty tanks filled with inert gas and there was no fire. Once, a shell broke off half the vertical stabilizer and broke the rudder completely off but the aircraft did not go into a spin and it reached its airfield.

Over Kerch', a Messerschmidt fired a round into the cockpit. The armored plate which the designer had designed in to protect the pilot saved him.

In pointing out the importance of ground attack aviation, Chief Air Marshall K. A. Vershinin[2] gives the following testimonial: "If the ground attack aircraft had not operated against the enemy's counterattacking tanks and men, the difficult situation which had developed for the army's forces would hardly have made it possible to hold the occupied bridgehead." In the literature devoted to the Great Patriotic War, weapons like the IL-2 ground attack aircraft, the Katyusha, the T-34 tank and the PPSH submachine gun are among the weapons which played an important role in achieving victory over the enemy.

During the difficult war years, there was a continual increase in the production of ground attack aircraft. The collectives of aircraft plants which were producing the IL-2's made colossal efforts to support the needs of the front.

With the development of this class of aircraft, the concept of aviation as a branch arm cooperating with ground-based weapons systems was confirmed and exploited; this was in contrast to General Douhet's concept on the air forces' independent role in military operations. In this respect, S. V. Il'yushin wrote:[3] "General Douhet's theory was repudiated in our country as being unwarranted and mistaken. We believed that the Air Force would be very important in any war in the near future as a weapons command for the ground army, that the Air Force would accomplish independent operations to bomb vital centers in the enemy's rear but it would not be able to decide the outcome of the war on its own.

"The experience of World War II confirmed that this point of view was correct. The outcome of the war was decided by large armies equipped with all types of modern equipment, including aircraft."

To achieve operational coordination between ground attack aviation and land forces to destroy the enemy's manpower, hardware and transportation facilities, it was necessary to build a low-altitude aircraft.

The IL-8, IL-10, IL-16 and IL-20 were built after the IL-2. During the era of turbine aircraft, the high-speed, twin jet IL-40 ground attack aircraft was built; it had exceptionally powerful weapons and bombing systems.

The first bombers were the CDB-26 and CDB-30. There were many modifications of the latter during its development and updating: the LRB-3 and LRB-3F (IL-4). The IL-4 long-range bomber was an all metal monoplane with two M-85 air-cooled engines, retractable gear and relatively small weight; it had a rather significant range, speed and load-carrying capacity.

The multi-role IL-4 was also the primary aircraft in Long-Range Aviation. By making long-range night flights, it delivered air strikes against Berlin and bombed military and industrial targets located in the heartland of the Hitlerites and their allies. This aircraft was in service from the beginning to the end of the war. Every night, hundreds of IL-4's were launched from their airfields and headed for the West. As a rule, they only returned toward morning and invariably with small losses or without any at all.

Before the war, besides the aircraft cited, S. V. Il'yushin's Experimental Design Bureau built the CDB-32 fighter (1938) with the AM-35 engine designed by A. A. Mikulin and the twin engine CDB-56 bomber (1940) with two AM-37 engines by the same designer. Testing of the latter aircraft was stopped due to the development of widespread series production of IL-2's and IL-4's.

The CDB-56 was the only prewar IL aircraft built as a high-wing monoplane and equipped with a twin (two end-fins) vertical tail section. The Experimental Design Bureau only used this design when they built the IL-32 transport (cargo) glider and the IL-76 transport aircraft.

At the end of the 40's, the first domestic tactical jet bomber--the IL-28 with two engines designed by V. Ya. Klimov--entered service with the Soviet Union's Air Force. Bomber aviation pilots quickly mastered it and gave the aircraft high marks. The IL-28 was produced in a large series and was in service with many countries which were friendly to us. For the comprehensive utilization of this aircraft, several versions of it were designed and produced. The IL-28, which developed high acceleration, like all the IL aircraft, was exceptionally easy to control and had good stability and maneuverability.

In addition to its superior flying and operational performance, production workers were especially attracted by its technological effectiveness: manufacturing simplicity and low labor intensiveness. A new industrial method suggested by S. V. Il'yushin played the primary role in this. The decision was made to cut the wing, stabilizer and fuselage along their axes so that each of the units was made up of two half sections. This separation ensured high quality riveting, opened the way for easy access to any part during assembly and made it possible to assemble difficult units outside the aircraft on workbenches.

The experimental IL-22 was the predecessor of the IL-28. The purpose of building it was to study many problems of jet aviation. After the IL-28, the IL-46 and IL-54 jet bombers were designed and built.

Having already foreseen a swift victory in 1943 at the very height of the war, S. V. Il'yushin and his group began to design the IL-12 airliner; they decided to build this aircraft with performance characteristics which surpassed those for aircraft in existence abroad at that time. With this aircraft, a new direction was formulated in the development of domestic aviation; this direction was characterized by a desire for highly economical aircraft.

Moreover, the concept of air transport safety was also being developed. At this point, it should be especially noted that, for the Il'yushin group, the requirement for safety runs like a red thread through all aircraft systems planning, design, tests and development processes. A high degree of safety is achieved by choosing the number of engines, the aerodynamic configuration for the aircraft and thoroughly developed control systems and by building an airframe with a long service life and by improving the reliability of all systems, power plants and equipment. For example, fire safety should not only be ensured by special purpose fire extinguishers but it should also be designed into the aircraft configuration, power plant fuel system equipment and various equipment systems.

Handling ease and simplicity not only make the crew's working conditions easier but they also promote improved flight safety to a significant degree. A lack of any delay in the aircraft's response to the controls and smoothly functioning control systems are inherent qualities in all the IL aircraft, including the heaviest one, the IL-62.

The Civil Air Fleets of the Soviet Union and the socialist countries have successfully used the IL-12's and IL-14's for a number of decades.

The widespread employment of the IL-12's and the IL-14's under the most diverse geographical conditions has shown that these aircraft were as good as the best foreign aircraft at that time in flying performance, economy and flying safety.

On the first postwar airliner, the IL-12 with two piston engines designed by A. D. Shvetsov (see Appendix), high standards were developed both for flight safety and for the arrangement of inflight services and comfort. It might seem strange now, but the design of furnishings was a difficult problem for aircraft designers while the first high-volume airliner was being developed. Thus, for example, the comfortable, soft seats in modern airliners were not built right away. Suffice it to say that the seats in the IL-62 are exactly twice as soft as those on the IL-12.

Just like the IL-12, the IL-14 is a twin-engine monoplane with a low-set, tapered cantilever wing. One of the most difficult problems in developing these aircraft with a twin-engine design was finding trade-offs between operational economy and safety during take-off when a single engine failed. Comprehensive theoretical and experimental studies made it possible to find an optimal solution to this problem. Thus, a high degree of safety is specifically ensured for the IL-14 by the fact that it can not only continue level flight when one of the engines stops but it can also climb in the event it fails on take-off.

Another difficult problem was formulating superior stability and controllability. This problem was solved through structural selections, wind tunnel tests of a large number of models and flight tests.

In the tracks of Il'yushin's first airliners, the new, multi-seat IL-18 airliner, with four ASH-73 piston engines designed by A. D. Shvetsov, lifted off from Moscow's Central M. V. Frunze Airport in 1947. Like its predecessors, this aircraft met the state of the art for similar foreign aircraft (for example, the American Douglas Company's DC-4) in flying performance, weight and other characteristics.

With a take-off weight of 42,000 kg, the piston engine IL-18 was designed for 60 passengers with first-class accommodations. The aircraft successfully passed the flight tests.

The era of jet aviation development arrived and the Experimental Design Bureau group headed by S. V. Il'yushin was engaged in the design of new equipment for air transport. Along with the development of the IL-22, IL-28, IL-30, IL-40, IL-46 and IL-54 military jet aircraft, they developed a design for and built a small series of IL-18 turbo-prop aircraft with four engines designed by N. D. Kuznetsov at first, and later by A. G. Ivchenko. The latter version was adopted for operational use.

The primary difference between the IL-18 and the previous generation of aircraft was its enhanced productivity. This is explained by the fact that cruising speed increased by a factor of two while the cargo-carrying capacity increased by a factor of four. The IL-18, which only weighs 3.5 times as much as the IL-14 and is only 1.5 times larger, can accomplish the same amount of work as eight IL-14's. Moreover, the time expended and the service cost on the IL-18 are significantly lower.

There was a sharp jump in the annual growth rate for the volume of air transportation services in 1959, when this figure significantly exceeded the corresponding statistics for previous years. This was the year of the widespread introduction of new jet equipment. The IL-18 and AN-10 airliners arrived on the airways to supplement the TU-104; this made it possible to quickly raise the productivity of the aircraft fleet. At that time, it was possible to reduce the ticket cost to the cost of a trip on the railroad and thereby guarantee a sharp increase in the stream of passengers on various sizes of routes.

The IL-18's with the AI-20 engines (the first flight of a prototype was on 4 July 1957) are carrying out large-scale passenger transportation both in the Soviet Union and in other countries of the world. Airlines in Europe, Asia and Africa have bought it and are successfully using it. Polar pilots have made joint record-breaking trips from the USSR to the Antarctic on two occasions in IL-18's and AN-10's. Members of the Soviet government as well as our astronauts and various delegations have made friendly visits to many countries on the IL-18.

Flight testing of the IL-62 intercontinental jet airliner with four turbo-fan engines designed by N. D. Kuznetsov began in 1963. This modern airliner, whose design incorporates the best engineering and scientific achievements of the world's aviation, electronics and other industrial sectors, can carry 186 passengers in its comfortable cabins on long-range trips at speeds of 850-920 km/hr.

The superior flight safety of this airliner specifically consists of the fact that it can continue take-off when one engine fails and it can continue flying when two engines fail and it can make another circuit on approach with one or two engines feathered.

Locating the engines in the rear raised a lot of difficult problems for the designers; the successful solution of these problems promoted the achievement of a high degree of economic efficiency, a higher level of flight safety and greater comfort than on existing aircraft with the engines located under the wing.

It is well known that engines mounted on the tail have a certain cost in weight. However, due to the fundamentally new solutions adopted during the design of the IL-62, they were able to build an airframe with tail-mounted engines whose weight efficiency was almost as good as similar foreign aircraft (the Boeing 707 and DC-8) with a lighter (in weight) wing-mounted engine configuration.

S. V. Il'yushin's Experimental Design Bureau's inherent style of designing aircraft with a high degree of weight efficiency was maintained during the IL-62's development. As a result, even with its somewhat larger wings and fuselage, this aircraft has a lower airframe weight than the British Super VC-10 which is in the same class and, consequently, it has a greater load-carrying capacity, i.e., a greater load ratio.

This is how it developed that the aircraft designed by S. V. Il'yushin have always been the primary and most high-volume aircraft for a given purpose.

An American magazine pointed out that Il'yushin's well-known IL-2 and IL-10 ground attack aircraft, IL-4 and IL-28 bombers and IL-12, IL-14 and IL-18 transports have gained international recognition as aircraft which perform their roles magnificently. The magazine emphasized that Il'yushin never displayed a taste for chasing after appearances; he used classical designs for his most successful aircraft.

While pointing out that the Il'yushin IL-62 four-engine turbo-jet had proven its effectiveness both in the sense of engineering performance and in the sense of basic passenger comforts, another American magazine concluded that the IL-62 did not leave any doubt that Soviet aviation could proceed on a par with the leading western airlines. This was written soon after Aeroflot's IL-62 flagship had linked the cities of New York, New Delhi, Montreal and Tokyo with the capital of our motherland.

Throughout the 40 years of Sergey Vladimirovich Il'yushin's creative work, approximately 40 aircraft types and modifications to them were built according to his plans and under his leadership. All the aircraft adopted for service and operational use in air transportation have been advanced, series produced and durable.

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CHAPTER 12

IL'YUSHIN AND HIS SCHOOL OF AIRCRAFT PRODUCTION

V. M. Sheynin, candidate of engineering sciences and
Lenin Prize Winner

Sergey Vladimirovich Il'yushin

The story of any type of equipment, including aircraft, begins with the engineers whose creative ideas and persistent work created it. Therefore, an examination of the basic principles of Il'yushin's school as a trend in aviation development should naturally be preceeded by a brief analysis of Sergey Vladimirovich Il'yushin's work traits and truly remarkable human qualities. Especially since the character, various aspects of talent and "moral qualities of an outstanding person,"--as Albert Einstein pointed out,--"are possibly of greater importance...than his purely intellectual achievements. The latter is a great deal more dependent upon greatness of character than is usually accepted."[1]

My attempt to do a creative portrait may be beneficial and, I hope, objective because I had the good fortune of working under the direct supervision of Sergey Vladimirovich Il'yushin for a period of 30 years and, as one of the people on the cutting edge, I met with him almost on a daily basis. This makes it possible to stake a claim to the authenticity of everything stated below.

Academician S. V. Il'yushin belongs to the group of outstanding designers whose creative work goes beyond the bounds of purely engineering work and becomes the work of a scientist. His exceptional success at his job was not only established by his talent as an engineer and scientist but also by his talent as a manager. However, only a combination of talent and a capacity for work bears fruit and Il'yushin was given a full measure of both. His creative work forcefully displayed far-sightedness and efficiency, a sense of purpose and persistence, concentration and conviction and, finally, a system. A system in everything--large or small: in thinking, studying, managing.

Let's examine the traits of this creative man and manager in more detail; but, first, let's explain the difference between the engineer's work and the scientist's work. Evidently, this difference is that it is not enough for the former to understand things, he must produce while it is not enough for the scientist to produce, he must understand things. The talent of the engineer and scientist were harmoniously combined in Sergey Vladimirovich. While producing, he attempted to penetrate the physical meaning of phenomena and gain an in-depth understanding which, in turn, helped him perform.

/Far-sightedness and efficiency./ The far-sightedness of a scientist or engineer is an innate gift and the fruit of study, or rather, not inherent far-sightedness but an analytical habit of the mind which is able to forsee things. S. V. Il'yushin's creative work confirms this and shows that this foresight is not based on experience although the importance of it cannot be denied. His first aircraft, the IL-2 and IL-4, were developed a comparatively long period of time before the war; they were built in record-breaking numbers and remained in service with the Soviet Armed Forces during the war up to the last engagements. While the IL-2 ground attack aircraft was, as pointed out by PRAVDA in August 1944, a magnificent weapon and had no competition from the aircraft in service with the belligerents, the IL-4 was the Air Force's primary long-range bomber. This kind of success is not only the result of his far-sightedness but also his lack of tolerance for premature, ill-considered decisions and his desire to incorporate the latest scientific discoveries and bold innovations. During the war, the central newspapers wrote of the IL-2 ground attack aircraft that it was not simply an achievement of aviation science but also a remarkable tactical discovery based on a profound, accurate idea.

The IL-2 ground attack aircraft was the beginning of the development of a new class of military aircraft and it gave birth to new tactics for employing it.

A creative group manager's farsightedness is of enormous importance since it not only determines his personal success and the success of the entire organization but also has an effect on the development of aviation as a whole.

The source of Sergey Vladimirovich's scientific foresight was his ability to analyze not only the ways for developing aircraft equipment but also the tactics of the air war (when developing military aircraft) or the economics of air transport (when developing airliners). As a result, S. V. Il'yushin built the aircraft of the future. Many factors established the high quality of these aircraft. Their production in record-breaking numbers is a vivid confirmation of this fact. But, that is not all. Very few aircraft in the history of world aviation can compete with them in service life. For example, the IL-18 was in production for over 10 years and its service life was 20 years. The same can be said about Il'yushin's other civilian aircraft. After all, "Il'yushin was an entire era in postwar civil aircraft produciton," said Artem Ivanovich Mikoyan, a man of profound inner nobility and a talented Soviet aircraft designer.

Many things typify the efficiency of the engineer and manager: personnel selection and the ability to trust them, accurate planning and a rational distribution of responsibilities, and many other factors. And, last but not least, brevity in expressing ideas. Verbosity is a characteristic of most people. Brevity is a rare gift. Feuchtwanger once stated that it takes a man two years to learn to talk and 50 years to learn to shut-up. To this can be added: a lifetime is not enough for some people to master brevity in stating an idea. It is not by accident that the saying goes "brevity is the sister of talent," and efficiency is even more so.

The laconic and precise statement of an idea which was always clear and complete was simply inherent in S. V. Il'yushin. He could truly be quickly understood. For this reason, the designer-general's engineering councils and other conferences were always distinguished by their strict efficiency. The same can be said for the designers' drafting stands and the estimators' work desks. Incidentally, it should be pointed out that Sergey Vladimirovich always devoted a lot of time to working with the designers and estimators and he considered it his primary job. The nature of his brevity was not so much saving his work time and the time of the major specialists, although this was important, as it was in mobilizing action for a precisely formulated task. Verbosity usually leads to uncertainty and, at times, simply confuses people. If a man says little, his words are important, especially, if his speech is distinguished by clarity of exposition and indisputable proof.

There is a saying: before learning to talk, learn to listen. Sergey Vladimirovich never took notes of meetings of the engineering council. Reports came one after the other and discussion began. He directed it with remarks and leading questions. He spoke last and answered a lot of questions having remembered everything. He had the surprising ability of being able to listen to a statement and to his neighbor and notice everything.

He liked discussion during the meetings and in private conversation. At first, you wondered why he was wasting so much time to convince you and then it became clear: in an argument, your partner lays out everything; new ideas arise and concepts develop. This is how he implemented his principle to the hilt: the manager must look at things through the eyes of all his assistants. No matter how good his eyes are, they are not enough.

Sergey Vladimirovich's example reconfirms an age-old truth that, in life, it is very important to do everything well no matter what it is: from being able to listen to your conversation partner to solving difficult creative problems. People who have the ability to do everything well are also distinguished by their ability to see any undertaking through to its logical conclusion, i.e., they have a sense of completeness.

Another manifestation of S. V. Il'yushin's efficiency was his decision-making style. His decisions were distinguished by their thorough, comprehensive consideration, logical elegance and engineering simplicity. He had another characteristic: Sergey Vladimirovich never insisted (for the sake of imaginary authority) on his decisions if he suddenly discovered better ones. He led the discussions with his assistants as an equal while trying to convince them that his ideas were correct but he was not stuck with it. It should be pointed out that this approach, which is also characteristic of a person's modesty, is only inherent in people with a great deal of knowledge. These are the people who have another inherent trait--they are never embarassed to admit that they don't know something. As a rule, weak people will never admit this.

Concentration is an invariable feature of efficiency. A great deal of concentration is necessary to analyze any idea, to promote the planned advance of engineering decisinns and the very process of planning and to keep events from interrupting you and disrupting the rhythm of creativity. This characteristic is easily spotted during emergencies and serious accidents. Unfortunately, aviation cannot yet dispense with them. They create a distressing state of mind and, naturally, distract people from their current tasks. S. V. Il'yushin tried to exclude the slightest irritation or fuss. On the contrary, he displayed even greater efficiency in evaluating the situation and achieved even greater precision and particularity in assigning tasks and distributing work. All of this had a mobilizing and organizing effect and it inspired confidence and calmness. After examining these problems, he was able to switch over to the daily tasks of his creative work surprisingly quickly and completely. In these cases, his invariable concentration was especially effective.

Of course, examples of his concentration are not limited to this period. It was also manifested in his attitude toward multiple themes in design work--a problem which is understandably more important. The latter is distracting and it splits both thinking and effort. Therefore, the designer-general was not a proponent of multiple themes. To each of his students and assistants, he was always an example of rare integrity and concentration.

S. V. Il'yushin's efficiency was also manifested in his invariable accuracy, punctuality and keeping his word. There was a good saying about such people in the old days: he was an obliging person. This applied completely to Sergey Vladimirovich and it had a nuturing effect on the entire group. The group members' trust in their supervisor, which is specifically based on his keeping his word, is one of the necessary elements of authority.

Il'yushin had a rule: the designer must work in such a manner that the most experienced and nit-picking specialist would be able to say: "It can't be done better." This almost became their slogan.

Another rule of Il'yushin's creative work was his bold utilization of everything new: new engines and new equipment systems; while they were being operationally tested and put into series production, they won over a lot of people. They instilled confidence in their reliability and reduced the time period for developing aircraft. In short, continuity facilitates a lot of things and has a certain economic impact. At the same time, the new and progressive usually recoups its cost and promotes the development of airframes, technology and equipment systems.

The design organization built by Sergey Vladimirovich Il'yushin has an inherent striving toward a feasible combination of innovation in cardinal issues and continuity in design solutions. In the final analysis, this makes its specific style.

The eternal problem of making choices arises in many of the planning and design issues. It is well known that there is no end to the search for the best; but there are deadlines and they are frequently stringent. Then, it turns out that the best is an enemy of the good. Not everything can be scientifically optimized; intuition and a sense of proportion--a sense of proportion for the best--are required. The designer-general was endowed with these traits. This facilitated the development of equipment within the planned deadlines and with the performance adopted in the plan.

People frequently talk about boldness in solving scientific and engineering problems. Of course, this boldness is necessary but it is granted to knowledgeable people. With insufficient knowledge, it is fraught with serious consequences. In this context, boldness should not be construed as being what is called "discretionary decisions." In our day, there is hardly anybody who would defend the advisability of such decisions, especially on serious issues. A comprehensive economic and scientific analysis is now recognized as the only correct criterion for a decision. However, there are various kinds of boldness. As an analogy to the French saying "make haste slowly," it can be said that boldness should be displayed cautiously in aircraft engineering. S. V. Il'yushin's bold decisions were not only based on his in-depth knowledge of his job and his valuable intuition but also on his high confidence in his group's work.

/Management principles and the system of interpersonal relations./ The design organization built by S. V. Il'yushin was small during the initial period of its work. Sergey Vladimirovich believed that large jobs could be accomplished by a small force and he tried to minimize the cost of advanced design work. He proceeded on the assumption that there is a certain, perhaps critical, personnel strength both for scientific and design groups beyond which the organization becomes ineffective and even unmanageable. These limits are valid, of course, for a specific management system and correspond to a certain state of the art and development of planning methods.

One of the principles of Il'yushin's management system was personal participation in the decisions on basic issues and on many others. And, incidentally, this is where the designer-general displayed his feverish energy and surprising tirelessness. The creative, practical work of Sergey Vladimirovich serves as a vivid confirmation of the well-known rule "he who is able to appreciate time always has it at his disposal." He really managed his time by precisely planning it; he had time for everything. He allocated the lion's share of it to his creative work; he assigned contacts with external organizations almost completely to his deputies.

S. V. Il'yushin set up a simple scheme of subordination for his group--each supervisor coordinated the work of his subordinates with an exceptionally precise distribution of jobs. He handled the latter himself, giving it primary importance. Il'yushin did not see any need to supervise the work of the section chiefs who were under his direct management. He built his relations with them on the basis of absolute trust which was indispensible to the development of a sense of responsibility.

Furthermore, he was able to organize his relationships in such a manner that none of the people he managed felt like simple operators who were carrying out specific assignments. They always felt like full-scale participants in the total job. One of the "secrets" of his successful management is perhaps hidden in this principle. Another "secret" was contained in his organizational system which encompassed many principles--from the enterprise's structure to the system of interpersonal relations.

The numerous components which make up a manager's workstyle include, besides knowledge and creative activity, the ability to handle people--an important trait for everybody, especially a manager. It is not easy to make a participant out of a performer and free him from trivial scrutiny and supervision, but this is still not enough. To obtain the greatest creative return from each designer, it is necessary to create an environment where he will be the least concerned and upset about possible personal problems. The designer-general took this into account, showed his concern and did what he could in these situations.

Another of S. V. Il'yushin's principles as a manager was that each designer's growth did not boil down to advancing up the heirarchical ladder but it did lie in improving his skills and gaining knowledge. He not only formulated this principle, he invariably backed it up with action. He created an actual (and not formal) position for his employees in the group, provided incentives and commended them (morally and materially) in every way possible in accordance with this criterion. The most important things to him were knowledge and creative performance and not the official positions of individual people. Sergey Vladimirovich never sacrificed justice to a deference for rank in anything. It should be pointed out that when he had to choose between "justice or order," (factors which are frequently contradictory), he was able to find successful compromises.

This approach to his employees' growth and position within the group is not only attractive for its just nature, it also has a developmental value. His people were not drawn to rank--they were striving for knowledge. All of this taken together led to personnel continuity for the basic part of the group. Il'yushin's employees did not leave the organization even when they had extremely tempting offers. In other words, all of this led to a minimal turnover--and personnel turnover is an extremely serious problem.

A remarkable trait of the designer-general was his ability to infect people with his enthusiasm and attract them with his ideas without any persuasion. In this, as in everything else, he was a man of few words and people were attracted and inspired as if he had transferred his flame to them, a flame which was never extinguished in him no matter what he was doing. And, he was not only occupied with his favorite equipment but also with teaching. He did not spare any effort or time for this purpose and he was able to combine a solution to engineering problems with personnel development. He liberally shared his knowledge with them. Sergey Vladimirovich was always reserved and, at the same time, extremely sociable. He was able to win over young engineers and he was able to take an interest in their specific problems and help them solve them. Moreover, he had a surprisingly warm attitude toward young engineers, and most importantly, he respected them. Although conversations with him were not very long, they yielded a lot and were remembered for a long time. They helped gain an understanding of the internal mechanism of the designer's expertise and his frequently deeply hidden laws.

Sergey Vladimirovich understood that it was not enough to simply teach a person--he had to be developed, i.e., a certain style for working and thinking and a sense of conviction and responsibility had to be inculcated in him. Therefore, he not only taught them how to work and master the art of designing but also much more, for example, how to write business letters, technical documentation and articles. He also had his style in this--a terse, extremely clear and precise exposition. He taught them how to talk by correctly setting forth his own ideas. Young specialists really have to learn this. In engineering, as in science, philosophizing is not permitted; it is not only necessary to discuss and express your opinions in a definite logical sequence, it is also necessary to provide an engineering justification for them. This does not come easy to young people. Oral as well as written presentation of ideas polishes knowledge. Sergey Vladimirovich was among those people who believe that the only knowledge which is sufficient and profound is that which can be clearly expressed.

In a young engineer's life, a lot depends upon whether he will be able to find himself in time. This, as a rule, arises only after he has completed the institute, when the young specialist must take a liking to the job which has fallen to his lot and he must try to succeed at it, i.e., win his small victory at it while, at the same time, remembering that he cannot just win once, he must win every day. For this, he must "find a spark" in the work which should become the primary meaning of his life. Unfortunately, not everybody is successful at this. The young engineer pictures his future activities in a significantly broader scope than is really possible and then he is temporarily disillusioned. The manager and the group help him get over this and find himself.

Sergey Vladimirovich knew very well that teaching people how to work and inculcating certain skills in them was only half the job. It was necessary to use their knowledge intelligently. This required setting up an environment for creative work. Primarily, complete freedom of initiative and trust. He proceeded on the assumption that the young people's mistakes "would not reach the aircraft"--there were many stages where they would be detected. At the same time, independence and learning from mistakes was a superior teacher. Therefore, within the organization, they trusted very young employees with important jobs. They were assigned the design of rather complex systems or independent estimates. This inspired them, gave them faith in their abilities and committed them.

As a true engineer and scientist, S. V. Il'yushin supported all creative undertakings; he helped authors who were trying to write and inventors who were on the way to new solutions. He once told the author of this article: "In order to write scientific engineering articles and books, it is necessary to: read everything previously written on this topic and follow the literature on a systematic basis; do an in-depth analysis of the physical import of the phenomena; learn to analyze and generalize various cases; search out new principles; and improve existing methods and attempt to develop new ones--all of this expands the author's erudition and he becomes more than just an engineer. Consequently, writing articles and books is primarily beneficial to the author himself. But, the organization is also interested in strong specialists." The results of this approach are obvious--Experimental Design Bureau researchers published several hundred scientific engineering works. This number of published works is extremely significant for a design organization which is not in a scientific research field. The designers had numerous domestic and foreign patents for the most diverse types of inventions.

Sergey Vladimirovich developed major specialists who not only had superior qualifications and an exceptional capacity for work but they were also distinguished by a special workstyle which was peculiar to them. This is well known in aviation circles and the Il'yushin designers enjoy a great deal of prestige. The engineers and technicians who have worked here for decades or longer are proud of their membership in Il'yushin's organization. It is also well known that this organization is one of the most well-coordinated, disciplined and productive ones. The manager deserves a great deal of the credit for setting up and developing a group of single-minded, enthusiastic people, a group of experts who are distinguished by their complete mastery of their profession.

Everything mentioned above about the system of inter-personal relations completely matches Sergey Vladimirovich's character traits. He was an exceptionally modest and tactful, reserved and courteous, cordial and fascinating man, unaffected and accessible to everybody. He possessed an innate and exceptionally finely developed sense of tact and a profound inner nobility--qualities which are extremely rare. He had a good knowledge of and invariably follow all the rules of official and everyday ethics. There is a saying that "success (like power) spoils the man." This does not apply to Sergey Vladimirovich in the slightest degree. It is difficult to imagine a more modest man than Il'yushin. Furthermore, he was never satisfied with success. The group and its manager were never intoxicated by victory; they tried to achieve a situation where today's success would lead to tomorrow's. This was also the wisdom of Sergey Vladimirovich Il'yushin. And, let's recall, incidentally, that wisdom never appears where there is a lack of breadth in opinions, where there is not enough goodwill and where prejudice has found a place for itself.

S. V. Il'yushin was a man with a cordial, kind character, a man inclined to open discussions, and forgiving. He appreciated people's work performance.

A great manager who set high standards for himself and others, he never raised his voice in excess and did not blow up at his subordinates. His manner of addressing people informally was friendly. His subordinates knew that if Sergey Vladimirovich addressed them formally he was dissatisfied with the job. His comments sounded more like suggestions or reminders than like criticism. They had a stronger effect than any blow-ups. I automatically recall V. I. Lenin's words which boiled down to the fact that the only supervisors who resort to shouting and rudness are the ones who use it to compensate for their own imperfections.

The designer-general attached a great deal of significance to order and completeness. Actually, to a great extent, mathematical order in the estimates on aerodynamics, weight, strength and other matters ensures their accuracy and validity. A complete design blueprint provides a guarantee against random mistakes and instills confidence in the reliability of the design.

Sergey Vladimirovich was among a most interesting group of people--people who are absorbed in their interests. True, he did not have his own "Stradivarius." His passion, which had a complete hold on him, was for his creative work, his favorite aircraft. Engineering like "science per se is irrestibly attractive and it rewards its admirers with the same enjoyment that they devote to it."[2]

S. V. Il'yushin was an opponent of pomposity and superfluous ceremony; he did not like advertising. For example, the situation on the day that the next prototype IL aircraft was making its first flight was very ordinary, business-like and commonplace, but the aircraft's preparations were more thorough. He did not invite guests to the first flight so as not to create additional tension. This is how it usually was but, as with all rules, there were exceptions.

I remember a small but curious incident from the practical experience of our Experimental Design Bureau. At the end of the 40's, the piston engine IL-18 airliner was designed and built (it should not be confused with the turbo-prop IL-18 currently in operational use; they have very little in common). A lot of people wanted to show this aircraft in a fly-by. However, there was barely enough time to complete the job. But, then, the first flight was scheduled for a week or two before the fly-by. This time, a lot of people arrived to watch the first flight, and not just employees from the Experimental Design Bureau and plant but also representatives from the Ministry of the Aviation Industry, Aeroflot and many others.

The pre-flight systems check got underway. During the check, a malfunction was discovered in one of the small control motors for the cowling shutters. The flight was postponed until noon. The guests arrived again. The system checkout was okay. The crew took their places and, after giving some parting instructions, the designer-general left the side of the aircraft; the hatches were closed and the ramps were rolled out of the way. V. K. Kokkinaki, the aircraft commander, started engines. Suddenly, the flight-line chief, who was standing in front of the pilot's cockpit, raised his crossed arms in a sign that the engines should be shut down. While watching the aircraft, he had noticed that liquid was spurting out of one of the engine nacelles. The brake system line had burst. The flight was postponed to the next day. This time, nobody came. The aircraft took off without any caprice and completed a number of flights on subsequent days without any malfunctions and then participated in the fly-by. So, sometimes the aircraft themselves "maintain" the traditions of their designer.

However, it should be pointed out that, in any case, the first flight of a new aircraft is always a big event. For the group, this is not only the result of their searches and hesitation, it is also a test of their painstaking work. The pilot's radio report that "everything's A-okay" and good results during the subsequent debriefing where the impressions of the first flight are discussed, usually makes everybody happy; but, at the same time, nobody is overly reassured, i.e., the possibility of surprises is not excluded. They will still encounter problems when the systematic flights according to the comprehensive testing program get underway.

/The path to aviation./ Sergey Vladimirovich Il'yushin's first acquaintance with aviation took place in 1910 at Komendant Airfield near Peterburg where he saw the Farman and Bleriot aircraft; he watched them being serviced and he watched their successful and unsuccessful flights. Later, he said that was when he fell in love with aviation. This love grew into a dream which came true when he was drafted into the Armed Forces and sent to that very airfield to serve his committment. He was included in the team which took care of the acceptance committee for the Vuazen and Lebed'-12 aircraft. True, the soldier Il'yushin's first job was cleaning up the airfield and hangars; later, he became an aircraft engine specialist and mechanic; in 1917, he passed the pilot's examination. That was the beginning of his life in aviation; all of his thoughts were wrapped up in it.

For many years, S. V. Il'yushin retained his desire to fly aircraft. Subsequently, when he was already designer-general, he not only flew training and sports aircraft but also the bombers he developed. This helped the designer a lot in his engineering practice. It is not enough to have knowledge of the aircraft; it is necessary to have a feel for it in flight.

In 1918, S. V. Il'yushin joined the party. In May 1919, he was drafted into the Red Army where he became an aircraft maintenance man on the 6th Aviation Train for one of the Northern Front's armies.

Soon afterwards, Il'yushin was assigned as the commissar of this train and then, based on a decision from AF Headquarters, he was assigned as chief of the 15th Train located near Rostov.

When the Civil War was over, the country was reconstituting the national economy. Specialists were needed; a personnel problem had appeared. Sergey Vladimirovich already had substantial practical experience; he had learned a lot in the aircraft workshops. But, experience alone was not enough--he needed knowledge; he entered the Air Force Academy imeni Professor N. Ye. Zhukovskiy, where he not only studied and mastered science but also became an active member of glider societies. In 1923, he built a glider which he had designed called Mastyazhart and later, the Workers' School Student; in 1925, he built the Moscow glider.

After completing the academy in 1926, Sergey Vladimirovich was in charge of a section of the Air Force's Technological Committee. Under his leadership, performance requirements were drawn up, preliminary and engineering designs were reviewed, plans for building new aircraft equipment were developed and aircraft production experience was analyzed.

In 1931, S. V. Il'yushin was assigned as the chief of the Central Design Bureau where there were several teams being managed by the well-known designers N. N. Polikarpov, P. O. Sukhoy, D. P. Grigorovich, S. A. Kocherigin and V. A. Chizhevskiy.

In 1933, Il'yushin established his design bureau within the Central Design Bureau framework. At first, this was a small team primarily made up of young people who did not have enough experience. However, this team was destined to grow into one of the leading design groups over time and it was destined to develop the entire family of famous IL aircraft.

/The aircraft designer's creative work./ S. V. Il'yushin's activities as an aircraft designer took shape and developed during those far-off years when engineering creativity in developing aircraft resembled creativity in art to a great extent. In this process, a lot was based on trials, godsends and guesses--the results of talent, intuition and foresight. Planned research with mathematical methods of optimization have only appeared recently.

The nature of a design group manager's work changes over time; there is an evolution in creative work; during aviation's developmental period, it was primarily individual creativity. A great deal depended on the manager's talents.

Significant changes took place during the scientific and technological revolution. As is well known, this period is characterized by the intensified development of analytical methods, the development of mathematical systems for all types of knowledge and the formation of a collective nature in creative work.

As an individual, the chief designer's role in expanding the field of research, which has become comprehensive in nature, has seen continual change. While managing a design group meant making decisions in the first half of our century, it frequently means managing decision-making in our times. A lot of things have taken on new shapes but the tasks have not become any easier.

However, Sergey Vladimirovich has always been not just the conductor of a well-coordinated orchestra but also, invariably, a composer. His ideas, which were always very well considered, formed the foundation of all the aircraft developed by the group.

This is why he always directly managed all the Preliminary Design Bureau's work himself. Just like the first stage of a rocket, the Preliminary Design Bureau provides the momentum for moving ideas and plans. This is where all the issues which determine the aircraft's appearance are resolved; this is where the firm's engineering policy is formulated (the airframe design--this is like the second stage in the process of aircraft development). This is also where the actual requirement for developing a particular design is analyzed (forecast); this requirement does not always correspond with the customer's desires. Their tasks also consist of discovering the fit between new equipment capabilities and the future requirements of air transportation.

The range of problems solved by the Preliminary Design Bureau is rather broad; it encompasses the area from long-term studies to engineering trade-offs and it includes the design of overall views and schematic diagrams, various types of estimates, theoretical and experimental studies, modeling and prototype development and much more. Sergey Vladimirovich directly managed all of this on a daily basis. He dug into the work of all the bureau's sections, reviewed things and made decisions on a very broad range of issues. He signed the blueprints and estimates himself.

Sergey Vladimirovich did not limit himself to assigning tasks, although this was also extremely important. People who are far removed from engineering and science believe that the most difficult thing is problem solving. Actually, formulating the problem is just as difficult. Like the sculptor who only has a piece of clay in front of him at first sees a form, figure or group ahead of time, i.e., the final result, so, the engineer or scientist, in formulating a problem or specific task must foresee or have a good idea of the results a solution or study of them will bring. This idea was expressed very well in Academician B. N. Yur'yev's aphorism: "Scientific work begins at the end."

Another, also rather difficult part of problem solving is selecting the method and using it correctly. Many people engaged in design work, even engineers, frequently think that if a method has been developed or a formula has been deduced, then using them is a mechanical job. They say that everything will proceed just like using Newton's Binomial Theorem or the Pythagorean Theorem. In many cases, this may be so but it is far from being so all the time. Many methods of design estimates (and especially weight design) are more reminiscent of notes which various musicians use to achieve completely different and sometimes not even comparable effects.

S. V. Il'yushin did not limit himself to formulating problems. When he assigned them to the designers, he assigned them to himself at the same time and frequently participated in their solution. He could not be separated from the creative design process. He participated in all its stages: assigning the problems, looking for optimal solutions, analyzing results and discussing them. The latter was also a type of creative process. Therefore, he not only permitted objections, he approved of them. The more persistent and convincing his opponents were, the more respect they ellicited from him.

From what has been said, you should not get the impression that Sergey Vladimirovich Il'yushin only handled long-term and preliminary design problems while directly managing the Preliminary Design Bureau's work. He also handled a lot of working design problems, i.e., direct design work; moreover, he handled the most concrete problems in this process. Of course, it is clear that he did not always do this to the same extent. During some periods, he did it frequently and during others, rarely; but, Sergey Vladimirovich systematically visited the design sections, followed the progress of their work and took an active part in the search for optimal designs and in the solution of complex problems.

However, the long-term and preliminary design work is still the very heart of all the design organization's constructive activities and it is of utmost importance to the firm's success. To manage this process, the manager had to use a definite system.

Sergey Vladimirovich understood this very well. He had a lot of fundamental principles which he never changed.

Incidentally, it should be pointed out that people frequently believe that everything new is supposedly born in the bowels of scientific laboratories and only then does it lead to concrete engineering solutions. This is not always so. The problems which arise during the development of modern airliners are so complex and diverse and their solutions frequently are so general in nature that it is difficult at times to determine whether they are engineering or scientific problems.

The continual desire to review and improve the aircraft fleet brings about a requirement for swift development in aviation science, engineering and industry. By building newer and newer models, the designer is incorporating scientific achievements and automatically participating in the development of science. For example, the aerodynamic studies during wing optimization not only lead to the development of aircraft production but they also enrich science. The same is true regarding the various design estimating methodologies or technologies: the various solutions, frequently fundamentally new ones (patentable), develop entire industrial processes and have a large economic impact at the same time.

In the field of aviation, a great deal originates and develops not only in the institutes' laboratories but also in design organizations. This is where the problems usually arise (and this is also significant) and they are frequently solved jointly by the Experimental Design Bureau and the scientific research institute through studies and experiments. Consequently, not only does science have an effect on the process of aircraft development, but, to the contrary, the creative process has an effect on science, especially due to the fact that design practice frequently overtakes theoretical development.

At present, a creative approach is necessary in everything, especially in science and engineering. In these areas, everything must be done creatively from beginning to end. The beginning of design work must be creative; but, the final stage of development for a new aircraft--which includes putting the finishing touches on the aircraft after all kinds of tests and then introducing it into series production and operational use--also requires a creative approach. This is the attitude S. V. Il'yushin had toward this part of the job. He sent a large group of highly skilled specialists headed by a deputy chief designer to the series plants to introduce new models. In the overall scheme of the Experimental Design Bureau's design activities, the work connnected with putting the finishing touches on aircraft was always considered top priority. In short, S. V. Il'yushin attached a great deal of importance to these issues not because he believed that they were a primary area in the overall process of developing an aircraft but because he did not believe they were secondary.

The place that aircraft occupy in the total transportation system, their reliability, efficiency and safety also depend upon how the finishing touches will be put on all these systems and upon a multitude of other jobs connected with putting the aircraft into production and operational use.

S. V. Il'yushin is well known as the grand master of simple solutions; people in creative work know the complexity of design simplicity, the eternal travelling companion of truly significant engineering structures. Just as many facts which now seem completely obvious were painful and difficult in appearing, the simple design solutions which later seemed extremely clear and obvious did not appear all at once. And what is especially surprising, the path to these solutions led through numerous difficult alternatives.

Il'yushin literally strove for simplicity in everything: in the decisions which determined an aircraft's fate, in the layout of numerous aircraft systems and in the design of even the smallest units and parts: as a result, all the IL aircraft are distinguished by their surprising flying, maintenance and operational simplicity.

People frequently wonder about the secret of the creative successes of Il'yushin's group, successes which invariably led to an exceptionally high-volume and long life for all the aircraft they put into series production. It is clear that all of this was the result of many causes; the simplicity of their solutions was by no means in last place. It is not easy to discover the "secret." The designers were taken by surprise many times by, for example, such questions: how were you able to achieve such high stability and controllability or such a high load efficiency and economic efficiency?

Actually, in the literal sense of the word, there was no "secret," of course. In this respect, it would be appropriate to recall the words of Academician Lev Davidovich Landau: "Just don't try to solve any problems," he advised. "It is only necessary to work and the solution to the problem will appear by itself."[3]

This is why the difficulties mentioned above arose. Nobody defined the problem like this: solve the controllability or load problem.

Everybody simply worked on a number of issues related to these problems and they were successful.

The manager's superior intuition also helped develop promising aircraft. He not only knew about the various trends in design work but he also sensed or intuitively foresaw and foreordained the developmental trends in many areas of aircraft production. This could not help but have an effect on their success.

In short, S. V. Il'yushin had a liberal gift of talent and a great deal of "lift" which invariably guaranteed his ascent along the path of creativity without any "forced landings" or "a wing slip." As is well known, talent is the combination of all a person's capabilities, and primarily creative ones. The latter are composed of originality and enthusiasm, curiosity and resourcefulness, patience and restraint, tirelessness and energy, flexibility and being right, confidence and conviction and, of course, devotion to the job. Among the other traits which define talent, there is another one which is no less interesting--uniqueness. While each person is unique in some way, people with a great gift of talent are unique in a major way.

Everything in our list completely applies to S. V. Il'yushin, and, most of all conviction. After all, it is not by accident that there is a saying that conviction is the soul of creativity; in addition, it is to a significant degree the cause of success (combined, of course, with job knowledge). "In any work," S. V. Il'yushin said, "there must first be a flight of thought, creativity and conviction...." Sergey Vladimirovich had a high appreciation of knowledge and the capacity for work in people; but, those who were distinguished by their enthusiasm, confidence and conviction actually evoked his love. He tirelessly developed these wonderful feelings in the young specialists.

During those times, when the cost of designing prototypes was not very high and it did not take long to develop them, there was a practice of simultaneously designing several models of the same aircraft (as competition) for a particular assignment at different bureaus. Aleksandr Sergeyevich Yakovlev wrote about this kind of design for fighters in his book.[4] This was also the practice in bomber development. It frequently turned out that, based on the deadlines, S. V. Il'yushin's aircraft were not the first to arrive at the airfield but rather the last.

A definite principle and definite reasons can be discerned in this. The principle is hidden in the very nature of the creator of these aircraft.

He never hurried; he took a long time to give birth to his plans and he thought them over. Only when he was completely convinced of the requirement for the aircraft being considered and the correctness of his current concepts did he mobilize all efforts, his and the group's, while developing an exceptional amount of energy; at a good clip, he incorporated his ideas in the blueprints first and then in metal.

This sense of confidence in the final result made it possible for him to raise an issue to the highest level when necessary. An example of this is S. V. Il'yushin's letter to the Government regarding ground attack aircraft. It contained the designer's farsightedness and conviction, feelings which almost never let him down. We are citing this letter in its entirity; it is undoubtedly of historical interest and, in addition, it provides a vivid expression of the aircraft designer's individuality, his style and his manner of expressing his ideas (the letter is from the Experimental Design Bureau Archives):

With the current depth of defense and level of force organization and their enormous fire power (which will be directed at ground attack aviation), ground attack aviation will suffer very serious losses.

Our ground attack aircraft, both those in series production--the VULTI and the KAI-5 [Khar'kov Aviation Institute] (I. G. Neman, designer)--and the prototype Ivanov (P. O. Sukhoy, designer) and the Ivanov (I. G. Neman, designer), are very vulnerable since not a single vital part of these aircraft--the crew, engine, oil system or fuel system--is protected. This may seriously reduce the offensive capability of our ground attack aviation.

Therefore, there is a requirement today to develop an armored ground attack aircraft or, in other words, a flying tank, which has all its vital parts armored.

Recognizing the requirement for such an aircraft, I have been working on a solution to this difficult problem for a period of several months; the result was a design for an armored ground attack aircraft.

To implement this outstanding aircraft which will immeasurably increase the offensive capability of our ground attack aviation by giving it the capability of delivering crippling strikes against the enemy without any losses or with very slight losses on our side, I request that I be relieved of my duties as chief of the main committee and assigned to produce this aircraft for State Tests in November 1938.

The task of developing an armored ground attack aircraft is exceptionally difficult and involves a high level of engineering risk; but, I will enthusiastically undertake this job with complete confidence in its success.

Sergey Il'yushin
27 January, 1938

/Continuity in the generations./ Sergey Vladimirovich had a lot of students and followers. First of all, his successor, Designer-General Genrikh Vasil'yevich Novozhilov, was a direct protege of S. V. Il'yushin. He is strictly preserving and creatively developing the basic traditions of the Il'yushin school.

Such a well known figure in aviation as Designer-General Aleksandr Sergeyevich Yakovlev considers himself a student of S. V. Il'yushin. And, he really was; he borrowed a lot from his teacher, not just engineering design principles but also organizational principles. Like Il'yushin, Yakovlev rates order and completeness highly. He has his own vividly pronounced style, a style in everything--from the aesthetics of all the facilities in the enterprise he manages to the architecture of his aircraft. Here is another interesting fact: it was Il'yushin who discovered the aircraft designer's talent in Yakovlev; Aleksandr Sergeyevich wrote about this in his article in this anthology. They became acquainted with each other when Yakovlev was still a secondary school student; later, they became good friends and carried these warm feelings throughout their lives. Strong people are impressed by strong characters. This was mutual in this case.

Sergey Vladimirovich had the talent of guessing people's capabilities. While setting up his organization, he did not surround himself with major specialists but rather with beginners (they became major specialists later but, at that time, before the war, they were young people). These students and closest assistants who were with Il'yushin for many decades are frequently called the Il'yushin Guards. And, this was the group of specialists that he relied upon when he solved all kinds of problems; these were the people he produced with. His students were thoughtful engineers with initiative; they were distinguished by their enthusiasm, their steadfast, superior sense of responsibility, in-depth knowledge and broad intellectual outlook. They were engineers with conviction who boldly and stubbornly defended their ideas and suggestions; they were accustomed to expressing their opinions soundly. They were the people of that generation; they always took their ideas for the subject of their activities and their work.

The students learned a lot from their teacher: thinking with the logic of an engineer and being persistent at their jobs; they mastered Il'yushin's style of developing designs and estimates; they had an in-depth knowledge of his system of work organization and his interpersonal relationships and a lot, lot more.

Leonid Il'ich Brezhnev stated it very well: "A great scientist, a real teacher repeats himself in his students. The student adopts his teacher's ideological conviction, his attitude toward work, his scientific erudition and his work methods. Be worthy of your mentors... Give them the greatest joy a teacher can experience: the knowledge that his students surpassed him!" [5]

The helm of the "ship" built by Il'yushin, the helm by which Sergey Vladimirovich invariably stood for 45 years, was handed over to the talented designer G. V. Novozhilov. Retiring from the organization's administration due to illness, he was absolutely sure that it would continue to function like a well-ordered mechanism. Knowledgeable, experienced specialists, wisened by the solutions to many difficult aircraft planning, design, construction and testing problems, are in charge of all the echelons of this mechanism. He hoped that his successor, students and work colleagues would preserve the current traditions and principles upon which he had developed the group and upon which he had organized all his creative work.

Sergey Vladimirovich resigned from his duties as a responsible manager but he stayed on as a member of the Scientific Engineering Council and as a consultant to the Experimental Design Bureau.

The problem of continuity is not an easy one. In the past, several organizations lost their character or ceased to exist after the manager left. However, Il'yushin's organization was lucky; but, not by accident. Sergey Vladimirovich had prepared the transfer of the helm in such a well thought-out and timely manner that the ship did not even slow down: it is calmly continuing on its way in its own channel, gaining speed as before. During the change of leadership, the strength of the creative friendship between two generations of specialists was put to the test. The group also withstood this. Again, it was due to S. V. Il'yushin's farsightedness in his leadership. Nothing changed in the group. The same organizational structure and workstyle were maintained. As before, the designer-general himself manages the first stage of our multi-stage organization: the Preliminary Design Bureau and all its sections. He decisively precluded any change in the established traditions and elected to develop and improve these traditions, design methods and management principles. For this reason, all the section managers in this long-established, well-coordinated organization remained at their positions. When solving difficult problems, the group is still guided by the tried and true yardsticks; they frequently mull over how Sergey Vladimirovich would have solved a particular problem. As before, the newly developed aircraft are called IL's in honor of the school's founder, the firm's founder and the design group's leader.

All of these facts, and also the successful development of new designs, instill complete confidence in the Experimental Design Bureau's future success. By building on the traditions of its teacher, the Il'yushin group developed the modern IL-76 jet transport, which has already proven to be a highly efficient aircraft in operational use. In addition, it has turned out to have an extremely large capacity for modifications. The group's latest creation--the 350-seat, wide-bodied IL-86 passenger transport (airbus) which made its first flight in December 1976--is a new milestone in development.

All of these facts, as well as the successful design of the IL-76 transport and the 350-seat, wide-bodied IL-86 passenger transport (airbus), instill complete confidence in the group's future success.

It would be appropriate to point out that everything we have said would probably seem more life-like against a background of specific cases drawn from everyday practice to illustrate individual situations. But, unfortunately, this is almost impossible. The problem is that the aircraft designer's creative work, like his creation--the aircraft--consists of tens of thousands of parts and is made up of an endless number of small facts and elements. And, just as no single part describes the entire aircraft, individual cases do not define the designer's creative work or his special features. Only the aircraft which are the result of his creative work describe him, and not just the ideas and engineering concepts it incorporates but also his school and special features.

On 9 February 1977, after having lived a little less than 83 years, this outstanding engineer and truly remarkable man departed from this world.

It is difficult for his closest students, who worked with him shoulder to shoulder for several decades, to get acustomed to the idea that Sergey Vladimirovich is no longer among the living. After all, the people who knew him well are the ones who really loved him and have a right to say: "I'm glad that I worked with Il'yushin." People like Sergey Vladimirovich are remembered forever.

When facts, developments or events recede in history, there is usually a reevaluation of their value. This saying is not in vain: "Each generation rewrites history anew." It is easy to predict that, as Il'yushin's epoch in aviation (and, he undoubtedly created an epoch in aviation) recedes into the depths of history, his fame will not wither away, to the contrary, it will grow. Historians are not only studying the truly remarkable equipment he built but also many of the contemporary archives; and they will inevitably discover something new which is still not well known today or which has not been recognized or appreciated.

Less than a month before Sergey Vladimirovich's death, a bust--a sculptural portrait of one of the most talented Russian aircraft designers--was erected on a tall, dark-red pedestal in the city of Vologda, in one of its central squares where a small garden had been laid out. Perhaps, it does not completely resemble the features of his face, but the designer's will power and sense of purpose--his character and thoughts--thoughts of enormous depth, are expressed very well. A lot turned out well for O. M. Manizur, the sculptor--the shape, proportions and the match with the surrounding city environment.

This bust will now serve as a memorial to a man with a name of world reknown, an outstanding engineer of our times, an academician and thrice-honored Hero of Socialist Labor--Sergey Vladimirovich Il'yushin.

SCHOOLS OF ENGINEERING

The development of passenger aviation has its trends which are similar to the schools of science. They are linked to the names of designer-generals: O. K. Antonov, S. V. Il'yushin, A. N. Tupolev and A. S. Yakovlev. Their groups have their own vividly pronounced features, completely developed creative programs and engineering concepts, their own styles and their own traditions. The engineering policy which guaranteed the presence and development of various trends is a progressive one; it promotes swift growth in domestic aviation.

It would be appropriate to precede a review of certain features in the schools mentioned above with several words on the design group manager's role in developing new equipment. But, let's point out that the problem of the role of the individual or the group in the development of science and engineering, new theories and industrial systems is not a simple one in modern history. It is not simple because research methods and design methods have taken on a completely new character while large groups have become the participants in the creative design process.

Resorting again to an analogy between engineering and science, let's cite the words of Academician B. M. Kedrov in his report at the 13th International Congress on the History of Science, which was held in Moscow in 1971.[6] He said: "Science is made by individual people, the scientists, and without their activities there is no science and there is no history of it... The role of the scientist's personality, which incorporates the effect of the individual on the develoment of science, is still enormous in modern 'big' science with its inherent collectivism and the comprehensive nature of scientific research. Contrary to the opinion that science is now taking its place alongside industrial production as one of its sectors, the actions of the scientific group manager or the head of a scientific school are especially important."

Of course, it cannot be asserted that all of this applies equally to engineering. However, the role of the manager of a creative design group is also enormous like it is in science and it is also preserving its importance during the search for new design procedures based on optimization and the widespread employment of computers. Moreover, the success of these activities is not only affected by the manager's talent but also by his character and psychology, in short, by his individuality.

In analyzing the creative work of many aircraft design groups, it is easy to see that engineering has its school just like science. Two of the oldest schools--Tupolev's and Il'yushin's--developed within competing engineering ideas and this promoted progress not only in engineering but also in science.

S. V. Il'yushin defined his course as follows: "We are trying to achieve a perfect aircraft which is characterized by the best possible performance of its role, i.e., we are trying to achieve the highest combat capability for military aircraft and maximum productivity for civilian aircraft. Only aircraft which are completely carrying out their missions can remain in production and operational use for a long time."[7] A lot has been written about the aircraft he designed, the record-breaking numbers of them, their long life and their engineering efficiency.

The oldest group, Tupolev's, was formed during the developmental period of Soviet aviation. It developed many different aircraft. In defining his course, A. N. Tupolev said: "...The primary purpose of our work...is not so much to develop specific types of aircraft as it is to solve new problems in aircraft production."[8] This group carried out many of its manager's bold plans when it began to build aircraft out of light alloys.

At the end of the 60's, the new flagship of short-range aviation, the YAK-40 designed by A. S. Yakovlev, made its appearance in air transport; one of the Russian schools in the development of fighter aviation is linked to his name. Yakovlev's design bureau built many different kinds of aircraft, some of which became very popular in general aviation. The YAK-40 passenger aircraft, which is distinguished by the originality of its overall design and the uniqueness of its airframe, continues the development of aircraft for local airlines (previously, the design bureau had built the AIR-6 and the YAK-12 in this class). Their next aircraft was the trunk-route YAK-42.

Of the design bureaus mentioned, O. K. Antonov's Experimental Design Bureau is the youngest; but, a number of original designs have already been built here; among them are the smallest--the Little Bee [AN-14]--and the largest--Antheus [AN-22]--aircraft in Soviet aviation. The group's basic course was defined by its manager: "The characteristic feature of today's engineering is maximization, i.e., achieving the maximum results with minimum expenditures."[9] This group is characterized by its bold innovation not only in planning and design solutions but also in technological solutions.

During the development of Soviet turbine passenger aircraft, several fundamentally different ways of designing air transport equipment were apparent. One of them was the widespread employment of the principle of continuity. In other words, developing passenger aircraft based on previous models by not only making maximum use of structural elements but also parts, power plants, equipment or aerodynamic and overall configuration. The second trend was characterized by the development of multi-role aircraft; the third was characterized by the design of original, single role passenger aircraft and by refusing to use existing engines and parts of aircraft in operational use.

Each of these trends had its pros and cons and they all played a definite role in the development of civil aviation.

The aircraft in the first group were built with previously well-developed power plants and equipment systems and this facilitated a reduction in design time and in expenditures on prototypes and putting them into operational use. This had an economic impact since it is well known from world practice that the inescapable period of time required to develop systems and master new equipment does not make it possible to make as widespread use of aircraft in the first years as in subsequent years. Consequently, this trend led to a savings in time, a reduction in initial expenditures and, thereby, to increased economy during the initial period of operations. It's true that these expenditures would pay for themselves over a 2-3 year period in the worst case.

The aircraft in the second group, which were distinguished by their multiple-roles, could be easily converted for various types of cargo. The size of the fuselage, which was selected on the basis of these criteria, naturally led to a certain loss in economy and weight (for the passenger version). Further development of the basic idea for this group can be seen in the appearance of cargo-passenger aircraft whose size was selected according to criteria for the passenger version.

Aircraft in the third group (as compared to the first) demand greater time, greater resources for preliminary designs and also greater resources to build and test prototypes. At the same time, this makes it possible to make use of all the latest achievements in aerodynamics, engine building, technology, metallurgy and other sciences; this promotes the development of long-term aircraft and, in the final analysis, the swift development of aircraft engineering. Operational practice has shown that the aircraft in the third group are economically superior. As a result of this, it has become universal.

Design methods can also be distinguished by their approach to engine selection. The development of aircraft based on existing engines makes it possible to save time and to outdistance competing organizations. Designs based on advanced engines somewhat slows down the process of introducing an aircraft but it makes it possible to develop more modern equipment. However, the feasibility of concurrent aircraft and engine design is not self-evident for a number of reasons. First, the development of a new engine takes more time than the development of an aircraft and, second, it requires greater resources. If existing engines have a potential for development, a high service life and reliability, they may be preferable.

The problem touched on above--the degree of economic feasibility in continuity--is interesting and controversial. It is clear that it is not possible to develop any qualitatively new models without using assemblies, units or parts of systems from previous articles and also without using previously discovered design solutions. It is difficult to define the area for using the principles of continuity. This area should not run counter to a bold approach toward using everything new. At the same time, everything that has been operationally tested and put into series production saves a lot. This problem also has its optimal solutions. If the new leads to a definite qualitative leap forward, then it is preferable; if it does not further development, then selecting the new for the sake of the new cannot be supported. The eternal problem of choice, which arises in many design problems, is also reflected in this case.

The design practice of leading bureaus is characterized by a desire for a feasible combination of innovation in cardinal issues and continuity of design solutions; the degree of continuity is determined by finding the cumulative result and considering the impact of the negative factor which is sometimes called "lost opportunity cost." A rational, warranted use of the principle of continuity increases economy. Therefore, they do not discard the advantages provided for the community and they try to preserve the ties of continuity characteristic of a given family of aircraft.

The problem of continuity merges with the more general problem of standardization. In our day, it is hard to overrate its importance. Everything modern and progressive is undoubtedly standardized. Frequently, the degree of standardization is expressed in quantitative statistics (for example, in percentages); this is not correct. The cost of a single unit, for example, of a pump is not comparable to the cost of an engine. The cost expression of the degree of standardization (as a percentage of the total) is a more objective statistic.

In addition to the independent, frequently significantly distinct, trends in solving the general and basic issues of design and engineering policy formulation, each group also leaves a certain "signature" in the very design of passenger aircraft parts. Thus, while examining the structural elements of a wing or fuselage of a particular aircraft, an experienced engineer can decide whose aircraft it is--Il'yushin's or Tupolev's, Antonov's or Yakovlev's. He only has to understand the nature of this "signature" and see its basic features.

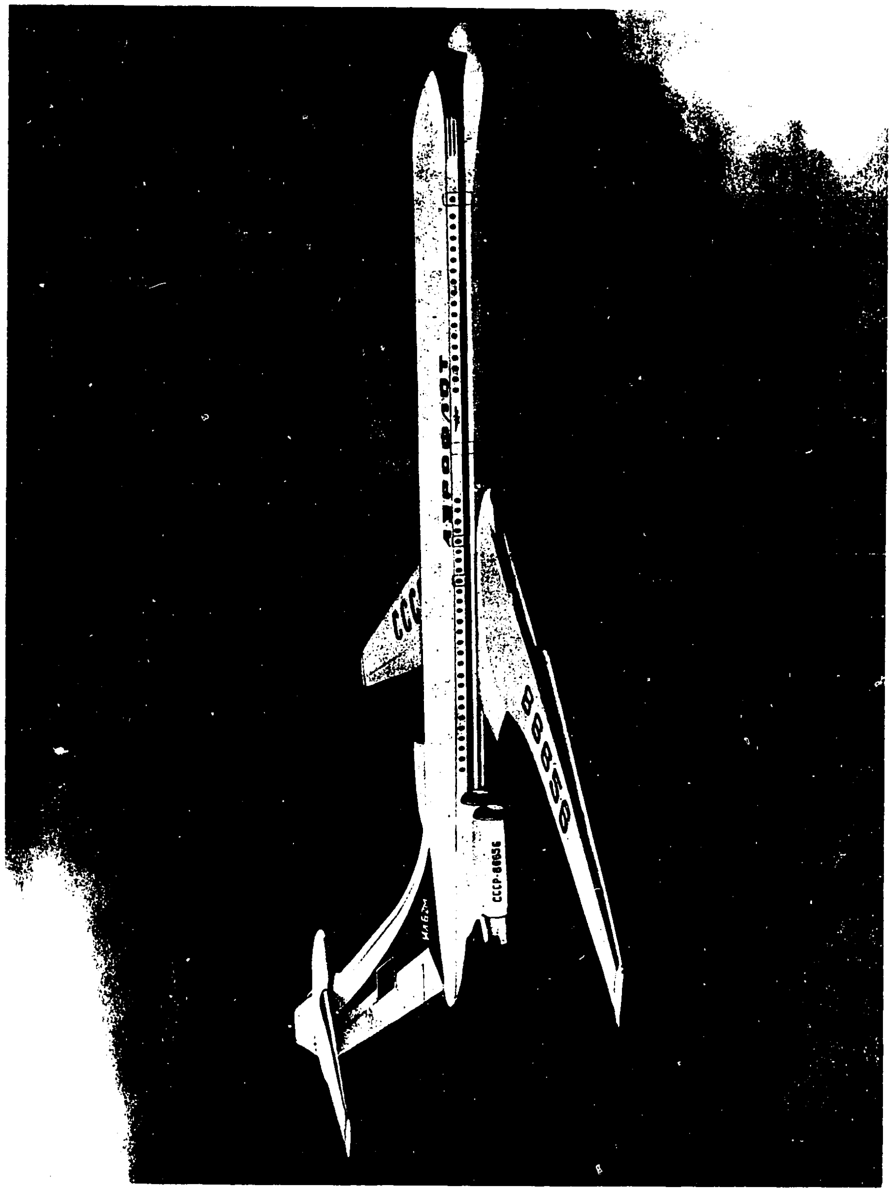
Il'yushin's course in aviation development was formulated when his first aircraft were built and it has continued to develop. Without any claims to comprehensiveness, the basic principles of this course (developed or adopted by S. V. Il'yushin) can be briefly defined by the following principles:

--an orientation toward the latest achievements in science and engineering and a refusal to use aircraft in one class to develop aircraft in another class (i.e., a refusal to design new aircraft based on existing aircraft with another role);

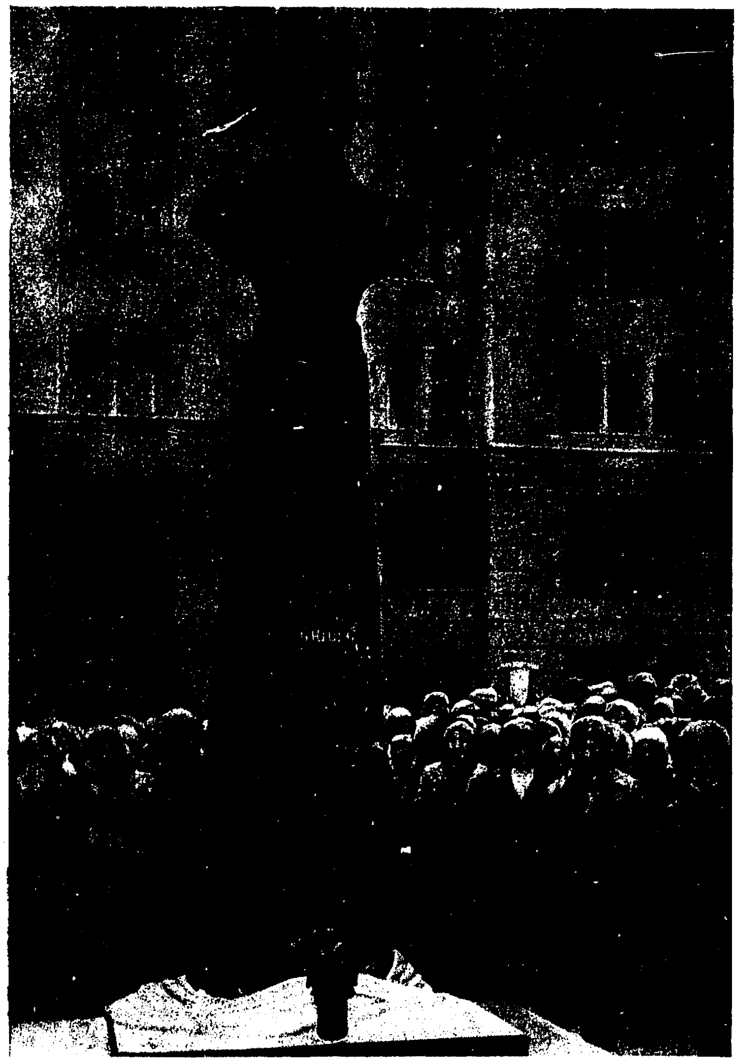
--a constant striving for aerodynamic, weight and economic efficiency; a search for optimal parameters;

1. S. V. Il'yushin among the designers who were awarded the Lenin Prize for developing the IL-76.

2. From left to Right: V. N. Ovcharov, D. V. Leshchiner, V. I. Smirnov, S. V. Il'yushin, Ya. A. Kutepov, G. V. Novozhilov, V. M. Sheynin



The IL-62 Airliner.



Bust of S. V. Il'yushin erected in Vologda on 14 January, 1977.

--the achievement of good maneuverability at high speeds (characteristics which are rather contradictory and difficult to achieve simultaneously);

--a quest for minimal structural weight and maximum utilization of capacity which leads to the most advantageous aircraft size for high load-carrying capacity;

--a quest during all design phases, in all design solutions and the design of schematics for equipment, to achieve maximum reliability, fail-safe operation and survivability;

--a quest for a harmonious combination of offensive and defensive weapons (active and passive) for ground attack aircraft and bombers;

--a quest for the technological effectiveness of designs in production and operational use, which is extremely important for mass production and high-volume use;

--a quest for the indispensable accomplishment of engineering requirements in all the performance characteristics of the aircraft being designed.

It would be ridiculous to claim that all these principles were only characteristic of S. V. Il'yushin's design bureau. Various organizations are guided by them to a certain degree. What is important is the exeptional attention Sergey Vladimirovich devoted to developing them in the very process of design work and the attention he devoted to realizing them as fully as possible.

The accomplishment of the latter rule was based on the marginal design method, specifically in selecting a specific aircraft dimension--the wing area. The same goes for the weight. S.V. Il'yushin stated on numerous occasions: "It is impossible to design without a margin for error."

The basic principle of Il'yushin's course, a principle which guarantees a high degree of efficiency in his aircraft, was his intensified development of the principle that design work is based on a combination of "size--weight--strength." Only a balance of these "three columns" which support the aircraft designer's art will lead to the development of highly efficient aircraft. Moreover, "size" is construed broadly. From the overall size of the aircraft to the size of each part (even a small one). The following principle of his school follows from this--develop compact aircraft, as he liked to say. Naturally, by invariably achieving the required productivity. And, he was right: like excessively "scaled-down" aircraft, over-sized aircraft were not viable. The size of IL aircraft only increased in strict accord with the development of equipment, and primarily aircraft engines. Examples of this are the medium-range passenger aircraft which were developed and are under development by Il'yushin's group.

Let's recall that the concept "size" not only includes the length of individual elements and the volume which is dependent upon this length but also equally includes aircraft mass which determines--to a significant extent--the size of the aircraft and evolutionary changes to it during the development of aviation. Therefore, the problem of size is inseparably linked to the problem of weight. The latter problem is among those which determine an aircraft's advantages and frequently its fate by having a direct effect on the combat performance of military aircraft or the economy of passenger aircraft. This is accepted as a fact now; however, it was not always so and not everybody ascribed equal importance to this. This principle was not a basic one everywhere for developing aircraft and designers.

It should be pointed out that Sergey Vladimirovich was one of the first aircraft designers to appreciate the special and frequently decisive importance of weight and size in aircraft development in the 30's. The expression "a compact design in aircraft" almost became a slogan for him. Combined with other factors, this had good results; the other factors included: high density for various load configurations and equipment systems, a feasible arrangement of the latter based on the shortest possible length of lines and minimal weight design. All of these measures were directed at developing an aircraft with a high load ratio. Using the reduced weight design method with a subsequent statistical test of the full estimated load also helps achieve this goal.

Frequently, the mission of the designers who were developing the assemblies, units, parts or schematics for aircraft equipment was limited to developing the blueprint. The strength and weight estimates were conducted by estimates engineers. The designers of Il'yushin's school not only develop designs in the general dimensions prescribed by the blueprint but they also do the estimates themselves. Moreover, they strive to achieve minimal weight while ensuring the required reliability, technological simplicity and least cost. The operating principle here is that, to a certain extent, the designer should be both an estimator and industrial engineer; he should have a good knowledge of weight control requirements and he should conduct the necessary estimates himself. Strictly speaking, this is a condition for optimal design work.

The desire to use the latest innovations in aircraft production can be illustrated by a number of cases from the practical aircraft design experience of S. V. Il'yushin's Experimental Design Bureau. The engines for the majority of the aircraft they developed for various roles were not selected from existing ones; as a rule, they were developed concurrently with the aircraft based on the latest achievements in engine building. The most modern wing aerodynamics and high-lift devices were used. They developed some firsts in domestic practice: a tankless fuel system, an AC aircraft electrical system and a high-pressure hydraulic system, tail-mounted engines on passenger aircraft with a new design for take-off and landing devices, fundamentally new industrial methods and others. Il'yushin's Experimental Design Bureau was the pioneer in using many progressive things: new material and titanium fasteners, a honey-comb structure and integral panels, a cascade and then clam shell jet engine thrust reversers, etc. In short, the Il'yushin designers were always path breakers on a large and small scale.

Everything that is truly new is always unexpected, always a surprise. Even though it has been prepared by the very process of development and by objective conditions. A certain sense of purpose is required in designing the new and implementing it; these efforts are always rewarded and, moreover, in many ways. Thus, the value of each of the innovations listed above for the aircraft as a whole is not limited to its role alone. They all affect various properties or characteristics of the aircraft, some to a greater extent, others to a lesser extent. For example, replacing the cascade reverser with the clam shell reverser led to an improvement in aircraft aerodynamics and to a reduction in fuel use. Another and more vivid example is the four-point gear design. It had an effect on certain dimensions for aircraft parts, on its internal and external configuration, on its weight and economic efficiency, on the improved reliability of a number of equipment systems and simplified maintenance for them, as well as on the baggage loading process. Moreover, the four-point design is an inherent property of this aircraft. For example, the same effect cannot be obtained on a finished aircraft by installing an additonal, fourth strut if its stability on the ground is not good enough. There would only be an operational gain; there would be a loss in weight.

It has already been mentioned that S. V. Il'yushin was never swayed by the obsession to develop an aircraft which was a "first." His principle was to develop aircraft at the state of the art. He did not hurry and his aircraft frequently arrived at the field after all his competitors; but, they were frequently given preference as the most efficient. This was the situation with the IL-2, the LRB-3 long-range bomber (its last modification was the IL-4), the IL-28 tactical jet bomber and the IL-18 airliner. In the IL-4 class, three aircraft of approximately equal size were developed. With regard to one of its "rivals," the LRB-3's superiority was obvious right after the tests; with respect to the other, it was obvious during the first years of the war.

Another example is the IL-28. Two concepts had developed in world aircraft production at that time. The proponents of one of the concepts had determined that high-speed bombers should not be equipped with defensive weapons. The other side believed that this was indispensable. Among the foreigners in the first group were the designers of the British Canberra (they only began to arm subsequent modifications of this aircraft). In the beginning, we also had some devotees in this camp.

In the age of high-speed jet aircraft, Sergey Vladimirovich Il'yushin remained true to his concept of aircraft invulnerability, specifically, reliable protection (active and passive) for the crew and the aircraft as a whole. Defensive weapons and armor plating are inherently linked to his aircraft's airframes, not only ground attack aircraft but bombers, too. True, the nature of the relationship was different. On the ground attack aircraft, the armor was integrated into the load-bearing structure; this was not the case on the bombers. But, when defensive weapons (of any type) are anticipated at the very beginning of design development, they have an effect on the choice of aircraft dimensions, weight characteristics and capacity. These problems are resolved by considering the most rational lay-out of defensive systems which will ensure operational efficiency in employing them. Another thing is interesting in this respect. Under S. V. Il'yushin's leadership, one of the Experimental Design Bureau's sections developed an extremely progressive gun mount for that time; it was called the IL-K6. Thus, the "aircraft" group solved problems which were not directly related to their primary area. They solved them because they were exceptionally important. It should be pointed out that it is difficult and risky to insist on your own ideas in a highly competitive environment without trying to "get around" the deadlines. The words of Designer General Semen Alekseyevich Lavochkin completely apply to S. V. Il'yushin: "...The person who chooses the easy path is forever doomed to make second-class articles; the person who chooses the easy path will never experience the joy of a job well done."[10] Sergey Vladimirovich experienced this joy on numerous occasions.

The IL-28 was the first Soviet jet bomber* introduced into the inventory of the country's Air Force. This does not contradict what was said previously to the effect that it was not one of the first prototypes to arrive at the airfield in the competition between two aircraft of the same type and size. Il'yushin's approach to bomber design--which consisted of a systematic combination of offensive and defensive systems and which became a tradition--guaranteed the superiority of the IL-28; many thousands of these aircraft were built at several plants. Moreover, like its predecessors, the IL-28 was "compact," i.e., it was a close-knit aircraft: there was a very high utilization of its capacity and the wing area was optimal. As a result, the aircraft had good weight and flying performance it was distinguished by its superior controllability and stability and, of course, it met all engineering requirements.

Another principle of the Il'yushin school which also found a vivid expression in the IL-28 was the concurrent development of new types of structures and new production methods. Or rather, the development of a structure which could be totally realized with the newly developed technology. The wing and other parts of this aircraft were in longitudinal sections which provided open assembly of the upper and lower parts of the wing. Sergey Vladimirovich proceeded on the assumption that, with a small number of changes, a tactical bomber could be reconfigured as a reconnaissance aircraft or torpedo bomber. Consequently, considering all the merits of the aircraft, such widespread employment held promise of exceptionally large-scale production of it. This meant that it had to be technologically effective and cheap.

It would probably be appropriate to talk about the "time factor" here. Is it always significant that a certain aircraft was first? When aviation was being established or when the time is right for the next revolutionary leap forward, when the feasibility of implementing fundamentally new ideas is being tested or when new routes are being developed at a range which was not previously attainable, the time factor is naturally of very great importance. Its role has noticeably declined at present. The fact is that aircraft are basically on an equal plane of development in different countries, or rather, there are small fluctuations in the state of the art. Any temporary superiority will not last long and will level out very quickly. Under these conditions, the impact of engineering and economic efficiency is more important than the time factor.

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* The TU-12 (based on the piston-engine TU-2), which was built previously, and the newly designed IL-22 were experimental aircraft.

An example, on the one hand, is the Comet and, on the other, the DC-8 and Boeing 707. Production of the former was quickly halted while the other two continued in production for a long time. However, it should not be forgotten that they took into account the sad experience of the Comet disaster; during the development of the Comet "virgin territory" was being explored and the designers encountered the phenomenon of fatigue strength and the repeated load effect. In the final analysis, what is important for civil aviation is not which aircraft goes into series production and operational use first but rather which one will be taken out of production last (naturally, considering aircraft from the same generation).

There are a lot of cases similar to those cited in the history of aviation. If you agree with what has been said--and it is possibly a controversial proposition--then it is easy to conclude that competition on deadlines for developing such expensive equipment is hardly advisable. The final result is more important.

You should not construe what has been said above as "first" versus successful. This was an attempt to illustrate the suitability of trends. Of course, it is clear that it is more difficult to develop the "first" aircraft than it is to develop subsequent ones; the entire issue is one of what we should strive for.

If the time factor important under certain conditions, then an optimal compromise between efficiency and the time for putting an aircraft into operational use may be found on the basis of a broad analysis. The importance of superior performance and low cost is obvious. The value of an earlier deadline for putting an aircraft into operational use requires thorough analysis. Cases where an obvious shortcoming is perceived in a certain type of equipment may be exceptions.

The single-parameter design of aircraft in the past, if it can be phrased this way, was similar to this, i.e., the desire to achieve an extremely high value for one of the parameters (for example, size or speed) to the detriment of the others. It is well known that the latter cannot be avoided. Aircraft can only be effective when there is a symmetrical combination of all parameters and they are optimized according to an economic criterion.

It should be pointed out that almost every aircraft which enters operational service has something original, something which it is "first" in or outstanding in, for example, size (the largest). But, not every "first" is efficient. For example, the size of aircraft, i.e., their dimensions and tonnage, has never been a problem (the basic problem has been and is efficiency).

If the factors mentioned above do not establish the level of engineering efficiency, what should be adopted as an objective criterion? What determines an aircraft's importance in the development of aviation? It is probably possible to acknowledge that the aircraft's production run and the length of its service life provide objective evidence about the merits of the aircraft. After all, it is practical experience that dialectics calls the criterion of truth. There are classical examples of the history of aviation which confirm this proposition: the PO-2, the IL-2 and YAK-9; the DC-3, IL-14 and the AN-2; and the Boeing 707 and the IL-18. N. N. Polikarpov's PO-2 was the most popular aircraft in the prewar period; it also played a well known role during the war. Its service life was extremely long. The "primary" aircraft of the Great Patriotic War was the IL-2; it laid the foundation for a new class of combat aircraft and it brought about new tactics for their employment; it had a record-breaking production run in the history of aviation--over 39,000 copies. The extremely efficient YAK-3, the lightest fighter, and the basic version of it, the YAK-1 and, later, the YAK-7 and YAK-9, were also distinguished by their exceptionally high-volume. The Douglas DC-3 airliner has been in operational service for over 35 years--it has set a record for service life. Alongside it is the IL-14, with a comparable production run. The three most mass-produced, piston-engine aircraft, the DC-3, the IL-14 and the AN-2, have also been used on a widespread basis during the era of jet aviation; the most mass-produced representatives of this era are the Boeing 707 and the IL-18. These aircraft have become sort of standards for foreign and domestic aviation respectively.

It's true that there are aircraft which are not distinguished by a very large number of copies produced or by a record breaking service life but which occupy a definite place in the history of aviation because they laid the foundation for a new trend. For example, the French Caravelle is among them. An entire generation of jet aircraft followed its configuration with the engines installed aft of the airliner fuselage. In addition, the Caravelle has had a number of modifications and is an instructive example of developing airliners via modifications.

Many of Il'yushin's aircraft laid the foundation for something new. It has already been mentioned that the IL-2 was the forefather of ground attack aviation. The IL-12 and IL-14 served as the foundation for developing large-scale air transportation within the Soviet Union and for organizing a transportation system.

Together with its peers, which were developed by other design bureaus, the IL-18 turbo-jet airliner promoted an increase in speed and comfort. In addition, it was not only distinguished by its high-volume operational use (due to its high economy) but, along with the helicopters designed by M. L. Mil', it is a high-volume export item. Foreign airlines are willingly buying the IL-18's. Finally, Aeroflot's flagship, the IL-62, laid the foundation for high-volume scheduled trips on distant international routes. It has linked the capital of our motherland and the capitals of the socialist countries with many cities on various continents.

The merits of these aircraft simultaneously led to their high production runs and long life. The secret of this success evidently consists of a rational combination of engineering capability and realistic requirements. There is a large gap between the appearance of a new engineering idea and the development of a practical system and there is also frequently a gap between the appearance of the idea and the appearance of a requirement for this system. Strictly speaking, this is tied up with the complexity of developing requirements which should be predicted years in advance and not determined based on the current situation. Moreover, the customer is not always able to reliably forecast these requirements; therefore, the designer also has to handle the solution to this problem. A similar situation is typical, for example, in American experience; Jack Steiner, a vice president of the Boeing Company, has directed attention to this on numerous occasions.

The ability to combine capabilities and requirements and the desire to do this has led to the development of the necessary aircraft with an optimal combination of basic performance data. This is a precise characterization of the Il'yushin school; the head of this school never tried to build the largest or fastest aircraft by sacrificing the other performance characteristics, for example, range or weight efficiency, if there was no requirement.

It should be recalled at this point that the desire for an optimal combination had already appeared during the initial period of S. V. Il'yushin's creative work, in the 30's, when he developed the design for the IL-2; this guaranteed his success. This desire was evidently based on the idea of optimization. True, the final formulation of this concept and the development of methods for it would appear later, in 25-30 years, in the 60's. At that time, the search for an optimal combination of speed and maneuverability, range and bomb load, firepower and armor was an extremely difficult task. It was well known that it was not possible to achieve the highest values for all these characteristics at the same time. But, which ones should be given preference and how could the most advantageous combination be discovered--this was a task which not only encompassed design problems but also tactical problems.

The first success for this approach to design work was the twin-engine CDB-26 bomber (the last modification of it was the IL-4). Built in 1936, it became the primary long-range bomber during the war. Approximately 7,000 IL-4's were built. They bombed Berlin. The first raid on military targets in the fully lighted city was carried out on the night of 7-8 August 1941. Thirty heavily-loaded IL-4 bombers took off from their dirt-strip airfield on Saarema Island and headed for Berlin. Later on, raids on the capital and other enemy cities were carried out from airfields near Moscow. The first raid in August was proof of the unsubstantiated nature of the Fascist Command's doctrine on the capital's invincibility: "Not a single stone will shake in Berlin from a foreign explosion. Germans can live in the capital safely." The IL-14 heartland bombers were just as much a surprise for the enemy as were the ground attack aircraft's crippling attacks against his hardware and men on the FEBA.

The next aircraft--the IL-2 ground attack aircraft--was an even greater success. In the minds of our people, it deserved its link to the label "legendary." With its powerful offensive and defensive weapons, the IL-2 ground attack aircraft supported Soviet Army combat operations and played an exceptional role in the rout of fascist forces. The fate of many decisive operations during the Great Patriotic War was determined by the participation of the IL-2 ground attack aircraft and later by the IL-10. The IL-2 was a complete surprise for the enemy's army; they had no previous knowledge of its existance and, during the war, they were not able to find the weapons or methods to repel its attacks and wage their combat operations. Enemy attempts to develop a similar ground attack aircraft were not successful. The impact from the IL-2's employment was staggering. Discharging "thunder and lightning" from their cannons, machine-guns and rockets and dropping hundreds of kilograms of all kinds of bombs, they destroyed hordes of men and equipment and sowed fear, panic and confusion.

Three basic lines of development--bomber, ground attack and passenger aviation--clearly took shape in the Il'yushin group's subsequent activities. Several types of aircraft were built in each of these classes.

Sergey Vladimirovich began designing his first airliner during the war while the military IL's were smashing the enemy. It is easy to notice one of S. V. Il'yushin's characteristic features in this--looking ahead and building the equipment of the future. He was the one who was able to develop weapons in advance for the war which was approaching at that time and, thereby, he made advance preparations for it (the long-range bomber appeared at airfields in 1936 and the IL-2 ground attack aircraft appeared in 1938). During the war, the designer-general prepared for the transition to peacetime engineering. The first postwar airliners in the swiftly developing air transport field were the IL-12 and IL-14. They were built in large numbers and were flown to all continents for many years. In the jet age, the IL-18 appeared at the airfields of the Soviet Union and of many of the world's countries after the TU-104 and AN-10; the IL-18 was destined to outlive all its rivals and to establish 22 world records in range, speed and load-carrying capacity (for this class of aircraft), i.e., in almost all its basic performance characteristics.

Then, the IL-62 intercontinental airliner with four NK-8 engines designed by N. D. Kuznetsov was built. Academician Mstislav Vsevolodovich Keldysh wrote about this aircraft: "based on its engineering and economic statistics, reliability and comfort, this aircraft is on a par with the best contemporary airliners in this class. It is not only safe in normal flight but also when it accidentally finds itself in an area of powerful air turbulence."[11] As if adding to this, Academician Vladimir Vasil'yevich Struminskiy stated: "The IL-62 is a new phase in aircraft production. It is a striking aircraft with its rigorous proportions, elegance and efficient shape."[12]

In foreign countries, widespread press reviews of the IL-62, which pointed out the aircraft's high state of the art and its high level of comfort, also matched the evaluations of specialists this time. The statement by the chief engineer of one of the largest American aircraft companies, Lockheed, Robert Ormsby, was typical of the latter evaluations.[14] [sic] After thoroughly looking over the aircraft, he held a press conference and stated: "The IL-62 has a good, skillfully developed practical design. It is a well-designed aircraft... The Russians are proud of their aircraft, and rightfully so. Il'yushin's IL-62 undoubtedly gives them cause for a great deal of satisfaction..."[15]

In conclusion, I would like to talk about aircraft modifications. Sergey Vladimirovich was one of the first designers to understand that it was not enough to build an aircraft at a high state of the art; even the most successful aircraft had to be continually improved and up-dated. After all, the state of the art, especially in aviation, is not known for its stability. In his conception of the role of modifications in developing aircraft, S. V. Il'yushin was a follower of Nikola Nikolayevich Polikarpov, whose talent he rated very highly. Incidentally, other common features can be found in their creative work. For example, N. N. Polikarpov was also a proponent of "compact" aircraft and he did not approve of gigantomania. His group was distinguished by exceptional productivity, just like Il'yushin's group.

With the exceptional complexity in aviation engineering, it is very important to develop aircraft by making modifications to them. This makes it possible to extend the aircraft's service life and to maintain its performance on a par with the continually increasing requirements for air transport.

Actually, all the IL airliners have been modified. The first one--the IL-12-- had the IL-12D; the IL-14 had the IL-14P, the IL-14M, the IL-14Gr, the IL-14S and all of them were used in large numbers. The IL-18 had even more modifications: the IL-18A, the IL-18B, the IL-18V, the IL-18D and the IL-18E. Each of these modifications had a larger passenger capacity, some of them had increased range and each of them had higher engineering and economic efficiency compared to their predecessors. The IL-62 also has its modification--the IL-62M which has significantly greater productivity and, consequently, economy on routes longer than 7,000 km.

The more complex and expensive an aircraft is, the more modifications it should have, with the stipulation, of course, that the basic (initial) version has the promise and capacity to be modified.

The above statements refer to the postwar period of the design bureau's creative work. However, even in the 30's Sergey Vladimirovich Il'yushin attached a great deal of importance to developing modifications and this is exactly how he achieved efficiency. There were several modifications to his first aircraft, the IL-2 and the IL-4. The operational effectiveness of the IL-2 was increased by reinforcing the gun weapons systems. For example, 37-mm cannons were installed on one of the modifications in place of the 23-mm ones. At this point, it is probably necessary to provide a warning against the mistaken assumption that the two-seat version was supposedly a modification of the single-seat version. This is not so. S. V. Il'yushin immediately proposed an aircraft with a second crew member--the gunner. He believed that passive defense (the armor) alone was not enough and that active defense, like a gun turret to cover the aircraft's tail section, was required. The single-seat version was built in the beginning. The first days of the war confirmed the correctness of the designer's position and they began to build the two-seater version of the aircraft. Another mistake is also made sometimes in viewing the IL-10 as a modification of the IL-2 ground attack aircraft. With a large or small modification, the appearance of the initial version nevertheless remains. The IL-10 is an aircraft with the same role as the IL-2 and it is a further development of it but it is not a modification of it. All its dimensions are different; it also has different aerodynamics, a different power plant and, of course, entirely different weight and flying performance.

The forefather of the IL family--the CDB-26--gave birth to advanced modifidations--the CDB-30, the LRB-3 and the LRB-3F (the IL-4). Moreover, efficiency was increased in a somewhat different way than in the cases reviewed above. In those cases, when the aircraft were modified, their combat (for military) and economic (for airliners) effectiveness was enhanced by improving the weapons systems or commercial efficiency. In these cases, the aerodynamics of the aircraft (specifically, the fuselage) were improved, the air foil was redesigned, there were changes in production technology, the mix of materials being used was revised, etc.

There is something singularly outstanding in the creative work of people, even people who have developed a lot of important items. For S. V. Il'yushin, it was the IL-2. If he had not developed a single aircraft besides this one, it alone would have been a sufficiently large contribution to the victory over the enemy and to the history of military aircraft development. Among domestic and foreign aircraft, there were a lot of really good ones and a lot which quickly died away; but, aircraft which were great events were encountered infrequently. The IL-2 ground attack aircraft was a great event. Great or small events are frequently associated with particular facts or subjects in people's minds. Thus, for many people of the older generation, their memories of the past war are linked to air raids, the song "This is a People's War," Erenburg's articles--he wrote over a thousand of them--and Simonov's poems. For those who spent their time on the front lines of the fatherland and the liberation of Europe, their memories are linked, in addition, to the Katyusha and mortars, the IL-2 ground attack aircraft and the T-34 tank. These were the main types of weapons which guaranteed our victory.

So, it became a custom--the people gave their own names to everything they liked: the rocket-launching artillery was Katyusha and the mortars were Vanyusha. The IL-2 ground attack aircraft had various names: "The Avenger," "The Work Horse of the War" and even "The Hunchback"--which carried a significant share of the burden on its hump. It was not by accident that a monument was erected to the IL-2, as well as to certain other types of weapons, on the tactical approaches to Moscow; this monument enshrines the wisdom of its developer, the creative work of his group and the heroism of the ground attack aircraft pilots.

A special place in the history of domestic aviation belongs to the aircraft designed by S. V. Il'yushin. This universal recognition has been expressed by making awards to the designer-general, his leading personnel and the group as a whole for their outstanding services to the development of aviation. Many aircraft with the IL emblem have been awarded State Prizes and the IL-18 and the IL-62, Aeroflot's flagship, were singled out for the highest decoration--the Lenin Prize.

We have already written about how the aircraft designed by Il'yushin have also invariably received high marks abroad. His talent and exceptional services also enjoy world-wide recognition. A vivid expression of this recognition is the case related by LtGen I. N. Kozhedub, thrice-honored Hero of the Soviet Union:[13] "Two candidates were submitted to the FAI [Federation Aviation Internationale]--the U.S. delegation submitted Pennel for the award. But, when J. F. Nilds, president of the U.S. National Aeronatique Association found out that we were suggesting that S. V. Il'yushin's services be singled out, he immediately withdrew his submission. 'I defer,' he said, 'to aircraft-designer Il'yushin; he deserves the Grand Gold Medal first.'"

It is said that a creative person's record of many years can be clearly seen from the top. The crowning glory and apex of Sergey Vladimirovich Il'yushin's creative work, the triumph of his engineering skill was the IL-62 intercontinental airliner. It was the last aircraft developed according to his plans and designed under his leadership. It was the culmination of the 45-year creative path from the IL-2 to the IL-62, a path measured by a large standard. All the aircraft on this path--both military and civilian--were aircraft on the cutting edge.

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CHAPTER 13

IL'YUSHIN'S "HANDBOOK FOR THE DESIGNER"

R. I. Rokityanskiy (deceased), design engineer

Designers in Il'yushin's bureau have been working for more than 40 years now, guided by the "Brief Handbook for the Designer (Basic Issues in Designing Aircraft Components, Assemblies and Parts)" developed by the designer-general.

The very fact that the designer-general wrote this document testifies to his high evaluation of the importance of the working design and the rank-and-file designer's contribution to the job of developing such a complex machine like the modern aircraft.

In his introduction to the handbook, S. V. Il'yushin wrote:

"After the aerodynamic and overall configuration of the aircraft has been turned out--after it has been shaped and sized, after the layout of the gear, controls, power plant, fuselage, wings, equipment, etc., has been drawn up--and also after the basic direction of the design has been determined, the second creative stage begins--designing the aircraft components, assemblies and parts."

While the design is being developed for any component of the aircraft--from a part to a unit--it will be necessary for the designer to consider numerous, as a rule, contradictory requirements which determine the shape, materials, weight and other characteristics of the item being designed. The value of Il'yushin's handbook lies in the fact that it helps the designer conduct an analysis (consider factors) on a methodical basis and be fully confident that nothing has been left out; as a result, it facilitates consideration of these factors during the developmental stage (formation) of the item.

The handbook not only provides a complete list of all the requirements which have an effect on design work but it also points out the requirement for a systematic approach to planning (i.e., considering the requirements for the item as a whole while designing the parts, assembly or unit) and it points out the value of a comprehensive analysis of all factors.

In his handbook, Sergey Vladimirovich wrote:

"Although these issues are set out as individual paragraphs, they are closely related, have a mutual effect on each other and a change in the process of designing any one of them will cause a change in many of the others which are related to it."

S. V. Il'yushin's advice to the designer was a very important supplement to the handbook; he gave this advice to his students on numerous occasions before they began to develop a design:

--look and see how a similar assembly was made on previous aircraft;

--look and see how this job was done on articles with approximately the same features;

--check to see how similar designs held up in operational use;

--study the new solutions which have appeared in fields which touch upon the operation, technology, etc., of the item which you are designing.

When reviewing the problems included in the handbook, it is methodologically advisable to divide them into several groups, combined according to their specific nature. In this article, I have used the latest edition of "Basic Issues in Designing Aircraft Components, Assemblies and Parts," which Sergey Vladimirovich prepared in December 1969.

/1. Purpose of the component, assembly, part or system. Ensuring their operation./ Sergey Vladimirovich always said that design work begins with these issues and the designer must take an especially careful approach to an analysis of them since the designer's work will be in vain if the design he is developing does not match the purpose and will not function.

While working on the problems of establishing the functional purpose of a part in an assembly, the designer must:

--precisely formulate (S. V. Il'yushin required that this be done in writing) the purpose of the item being designed;

--get acquainted with all the documents which formulate requirements (engineering specifications, engineering requirements);

--study, or compile if this was assigned to the designer himself, tasks for the item's design;

--study the "Flight Suitability Standards" and check to see if all the requirements have been included in the engineering tasks;

--consider the operational experience with previous, similar items, to the extent that it may make adjustments to the tasks obtained from outside;

--if the assembly being designed is related to the aircraft's aerodynamic shape, you must make sure that the shape is maintained when any load is placed on it or when the assembly (unit) is placed under stress and throughout the item's entire operational cycle;

--develop several versions of a functional diagram, evaluate the pros and cons of each version and justify the rationale for the diagram selected.

/2. Strength--weight./ The problem of providing the required strength for a given weight literally faces the designer throughout the entire design process. Sergey Vladimirovich devoted continual attention to the "strength-weight" problem; as a result, the load figures for his aircraft were always very high. The search for any optimal solution, from choosing the power plant to designing fasteners, includes a solution to this problem as a basic element of it. These two members of the well-known aviation formula: "aerodynamics--strength--weight" are so related to each other that problems concerning them must invariably be solved jointly.

While working on this group of problems, the designer must:

--obtain the weight limit and evaluate (statistically or according to an estimate) the feasibility of realizing it;

--select the correct criteria for a preliminary evaluation of the weight;

--distribute the total weight limit obtained over the components;

--make sure it matches the loads in the "strength standards"; check to see if all the estimated cases have been taken into account; match the minimal margin of strength which must be provided in the structure being designed;

--develop a load-carrying design (as a rule, do not limit yourself to a single alternative; develop several designs and conduct a strength analysis of each one).

The designer must provide an evaluation of each alternative from the point of view of weight, reliability and feasibility (while providing an evaluation of its technological effectiveness and economy at the same time) and he must formulate the advantages of the selected alternative:

--when analyzing the load-carrying design, evaluate its rigidity (by considering the effect of stress on the initial forces and moments);

--find structural shapes for the selected load-carrying design; conduct a comprehensive evaluation of their efficiency;

--determine (select) the most efficient material to build the structure; analyze the extent to which it has been tested by operational use in existing structures or through special research projects;

--familiarize yourself with the engineering requirements for the material and all its technological, operational and strength features; conduct a thorough analysis of the feasibility of using materials which are capable of significantly increasing the structure's load efficiency; when using new alloys, thoroughly consider their special features.

The material is not simply selected based on the strength requirements. It is necessary to check the fit between the material selected and the functional system or unit requirements, i.e., there must be a study of the problems of harmful contacts (chemical and electro-chemical), fire safety, etc.

Special attention must be paid to service life and strength safety (fatigue, low-endurance fatigue, safety when partially damaged, acoustic strength, etc.), i.e., this entire package of problems, including the selection of allowable stress which will guarantee the required service life; the elimination of stress concentration; duplication in important areas, etc.

Three of Il'yushin's basic rules should be added to this list of problems which the designer should cover while resolving the strength task; Sergey Vladimirovich always reminded his students of them when he was analyzing the design solutions they submitted:

--if you want to develop a light structure, absorb the force where it arises; don't let it "travel" along the frame for a long time--this will lead to excess weight;

--while testing the strength and reliability of the unit, assembly or part you designed, pay special attention to the spots where the "flow of force breaks off"--the possibility of a mistake is greatest at these points;

--always take structural stresses into account; they can lead to an unforeseen redistribution of forces.

3. Extended unit or system operations. Operational problems. Although these problems are related to ensuring operations and strength and although their accomplishment is always anticipated throughout the entire period of operational use, it is methodologically advisable to single out operational problems in a special section, as S. V. Il'yushin did in his handbook. They have occupied and continue to occupy one of the top, if not the top, priority in the Experimental Design Bureau's work. This guaranteed a high degree of maintainability, and, consequently, reliability for Il'yushin's aircraft. Sergey Vladimirovich himself always solved any problem which arose during operational use first and he demanded this from his subordinates.

In solving the problem of fulfilling all the requirements levied on a unit for a period of extended operation, the designer must do the following:

--precisely define the service life which the unit must have;

--check again to see that all the requirements related to the task of ensuring a lasting service life have been accomplished;

--check the item's testability, i.e., the possibility of approaching all the spots which are vital to service life and safety for an inspection while the item is operating;

--for areas which cannot be visually inspected, design fail-safe methods of instrument tests using optical or other special-purpose equipment; make sure there are non-destructive testing procedures for the structure;

--check the item's repairability, i.e., accessibility to disassemble the unit, replace individual parts and lubricate it; analyze the structure's maintainability;

--make sure industrial safety requirements are met for conducting all repair and periodic maintenance work;

--ensure reliable rust protection and check to make sure there are no harmful chemicals or electro-chemical contacts; develop a chart of the most reliable protective coverings;

--check to be sure the pressurization is protected against humidity, dirt and condensation and check to be sure there is sufficient drainage and the possibility of drying out (blowing out) the unit;

--develop optimal (by considering safety and economy) time periods for and the scope of preventive maintenance and periodic maintenance (the time periods for periodic maintenance must guarantee the serviceability of the systems and their units in accordance with the service life requirements).

The following also belong to this section:

--the determination and design of special tools and devices required in production and operational use;

--instructions for operational maintenance, including transportation and storage of units.

/4. Economy and production engineering./ During design work, the designer primarily takes economic efficiencey into account by looking for the most advantageous industrial engineering solutions. The design he selects must meet the requirements of series production and it must guarantee:

--convenient assembly and disassembly;

--unit interchangeability (complete or partial);

--maximum overall standardization and standardization of all components (their use in other parts of the item is preferred);

--maximum possible use of mechanization, especially for riveting and assembly jobs;

--that the principle of a low level of detailed work is maintained, with sufficient ruggedness to ensure survivability;

--the least possible number of operations to make parts and assemblies (for machined parts, provisions must be made to select economical intermediate products which approximate as much as possible the part's final form).

The designer must evaluate the feasibility of using modern industrial methods for manufacturing parts (casting, stamping, deep etching, welding, splicing, adhesive welding) by considering the volume.

It is necessary to thoroughly review the design of tolerances and requirements for clean parts surfaces; reliable maintenance for units must be taken into account since it has a relationship to the problem of parts deterioration and the possibility of so-called scores appearing which may reduce the service life and cause an operational malfunction. This also includes provisions for reliable lubrication.

Recently, the designer is also faced with additional problems of patentability and patent protection for designs; it is necessary to take these into account when developing new designs or using previous design solutions.

/5. Safety and reliability./ Although the basic requirement for an aircraft design--safety--must be taken into account by the designer throughout the entire design process, S. V. Il'yushin always recommended devoting the final stage of design work to a special analysis of this problem.

To check up on the accomplishment of safety requirements, the designer must direct his attention to the following problems again:

--the validity of the designed-in service life and periodicity of preventive maintenance and periodic maintenance for important air frame components and primary systems;

--the strength and serviceability of the basic load-carrying components of the airframe and control unit and systems, not only under normal conditions but also in extreme regimes as well as during malfunctions and partial damage;

--the accomplishment of all the requirements in "Flight Suitability Standards" and other similar documents, especially on fire safety and survivability during combat employment;

--test results of engineering solutions used in previous designs and similar items and shortcomings uncovered during operational use;

--have all the finished items been completely matched up, have all the requirements for their installation been fulfilled, have steps been taken to completely eliminate the possibility of incorrectly installing them during operational use of the aircraft;

--have steps been taken to prevent mistakes in assembling parts in the aircraft flight control system during operational use and maintenance, mistakes which may lead to malfunctions in the flight control system.

To manage the designer's work in analyzing designs, especially when checking reliability and safety, S. V. Il'yushin introduced a system of "unit and system design certificates" at the Experimental Design Bureau.

According to S. V. Il'yushin's concept, the purpose of the certificates was "to ensure that the aircraft did not have a single system or unit which had not been inspected or analyzed and that there were not any areas which would cause any doubt about their operational reliability."

For a visual demonstration of the analysis, provisions were made to make "posters of load-bearing designs which graphically depict the effect of forces" and composite blueprints which would facilitate the analysis of those areas where there was an overlap in the operation of several systems and where several units came together.

Let's cite the content of the standard "Unit Certificate" (for the blueprint design group) which was put into practice at the Experimental Design Bureau based on S. V. Il'yushin's instructions:

1. Unit schematic.
2. Engineering specifications for the design work, which must include the requirements for 1) operations; 2) strength and rigidity; 3) service life; 4) maintenance; 5) industrial engineering and economy; 6) interchangeability; and 7) repairability.

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3. Basic design principles adopted.
4. Materials being used (with a justification for their selection).
5. Load-bearing designs.
6. Estimated load diagrams.
7. List of strength and functional tests required.
8. Weight table, including the prescribed weight limit.
9. Table of increases in design weight (based on industrial engineering requirements, customer requirements, etc.
10. Test results.
11. Operational results.
12. Design changes resulting from the construction and use of prototypes and series vehicles.

The compilation of the certificates disciplined the designer's thinking and led to a situation where the design analysis, which was previously conducted unsystematically and incompletely, began to be conducted in an organized manner and, most importantly, with a scope that precluded the possibility of mistakes to the maximum possible extent.

In conclusion, I would like to talk about the traditional design principle adopted by S. V. Il'yushin's Experimental Design Bureau. When solving any problem which arises during his work, the designer will encounter a group of contradictory requirements. The correct solution is not simply a "suitable compromise." The basic problem must be singled out, the problem which is especially important for the given aircraft, unit, system or assembly--the requirement which determines the basic characteristic of the item being designed. All other requirements must be subordinated to this one.

Examples of such designs with a sense of purpose:

--Il'yushin's IL-2 armored ground attack aircraft; the entire design of this aircraft was subordinated to the problem of developing its invulnerability;

--the IL-28 wing which had a horizontal joint along the chord which made it possible to develop the precise, external contours for high-speed jet aircraft and made it possible to make maximum use of panels and machine riveting;

--Il'yushin's IL-18 and IL-62 airliners; their shape, configuration and parameters were selected on the basis of the primary requirement--guaranteeing efficient passenger transportation.

This principle--it can be called design work based on goal-directed compromises--form the foundation of S. V. Il'yushin's activities (when solving problems concerning the aircraft as a whole and its primary systems and units). His students use it on a widespread basis.

CHAPTER 14

ACADEMICIAN S. V. IL'YUSHIN'S ROLE IN THE DEVELOPMENT OF SCIENTIFIC AIRCRAFT DESIGN METHODS

A. A. Badyagin, professor and doctor of engineering sciences

Based on examples from the development of general aircraft design methods, it is interesting to follow Designer-General S. V. Il'yushin's role in establishing the principles for optimal (rational) design at the end of the 30's and beginning of the 40's when the statistical method was dominant.

As is well known, the first aircraft design methods were those of copying and similarity. For example, Clement Ader's Aeolus (1890) was a large-scale copy of a bat. The Gakkel'-9 (1912) was reminiscent of a soaring predator. The first passenger aircraft built by Louis Bleriot (1912) was similar to a postal coach with wings and a tail section. Later, these methods of copying and similarity were used, for example, during the development of the TU-104, the TU-114 (whose prototypes were military aircraft), the TU-124 (a smaller-scale copy of the TU-104) and others.

The use of these methods during the height of aviation was explained by the lack of information and experience. During the later stage of aircraft production, the methods of copying and similarity were used to save time and resources during aircraft development. At present, methods of copying and similarity are hardly used at all to select aircraft parameters; they have become the property of history, not to mention the fact that the systematic employment of these methods leads to being constantly behind and to a loss in economy in the aircraft copy.

The fact is that the conditions for employing an original aircraft are, as a rule, significantly different from the conditions for employing an aircraft copy. Therefore, the parameters of the aircraft copy are not optimal and, while they exist, the entire aircraft fleet loses a lot more in the way of resources than it saves with the development of an aircraft copy. Here is what Designer-General A. A. Tupolev wrote in this respect:[1]

"The engineering requirements for military and passenger aircraft are different. A high degree of reliability, comfort and economy are the requirements for an airliner which are sometimes hard to fulfill based on a bomber.

"So, it turns out that it is better to spend more time and resources to develop a new aircraft than to pay for all the advantages of reconfiguring an airliner with poor commercial performance."

In the 20's--30's, the statistical method of selecting an aircraft's basic parameters appeared in the tracks of the methods of copying and similarity; the statistical method was based on using a number of prototypes and not just one.

While, in their scientific level, the methods of copying and similarity correspond to the stage of active contemplation (a term from the theory of knowledge), the statistical method is characterized by some analysis. Based on the task and with statistical data on aircraft with similar roles, the designer tried to design an aircraft with the best performance.

The first Soviet aircraft weight engineer, P. M. Kreyson, was one of the creators of the statistical design method and an ardent proponent of it.[2,3] P. D. Samsonov was a follower of this method.[4]

At that time, it was recommended that the aircraft's basic parameters be selected using Everling Numbers.[5] The designer had to establish the Everling Numbers for his aircraft and compare them to the same numbers for the best aircraft. If the parameters selected were not successful, they were changed "by considering the statistics or personal experience" and then a new estimate was made.

At that time, aircraft were evaluated and compared according to their individual specifications. Compared to its prototypes, the best aircraft had greater speed, better load efficiency for the same range, etc. However, under the statistical design method, this evaluation only pushed the designer toward a quantitative increase in the figures and, essentially, slowed down the development of qualitatively new aircraft.

The statistical method for determining the aircraft's basic parameters and flight performance received further development in the works of A. L. Gimmel'farb.[6,7] He suggested an original method of "modifying aircraft statistics" and he pointed out situations where a particular aircraft parameter satisfies several requirements, for example, when the wing loading per square centimeter simultaneously meets the requirements for maximum speed and landing speed.

The statistical design method hypothesizes a task of extrapolating aircraft performance data and parameters so the aircraft is not obsolete by the time it is put into series production. The design problem is believed to be completely determinate: a single value is established for each of the parameters, based either on the statistics or the assigned requirements (limitations). This method is based on the assumptions of a continuing, smooth (without any sudden changes) change in aircraft parameters in performance and a sufficient number of prototypes. There was a developmental period (prior to jet aircraft) when these kinds of assumptions were warranted. However, during the present, swift, uneven development in aviation, the statistical method for selecting parameters and performance is not on firm ground since there either are not aircraft prototypes at all or there are not enough of them.

Two facts have a large effect on the developmental nature of modern aviation: the increase in the aircraft developmental cycle, from the beginning of design work to series production, and the colossal increase in the cost for building a modern aircraft. While this cycle (up to series production) was an average of four years in 1940, it has presently increased to 6-10 years. It is obvious that extrapolating statistics for 6-10 years is an extremely risky business. The cost of building certain foreign aircraft is shown in the table.

It is significant that none of these aircraft had any predecessors and each was a sort of one and only copy. No matter how rich a government is, it is not able to concurrently build a large number of such unique aircraft whose construction costs are comparable to the government's annual budget.*

Aircraft designs were now being thoroughly studied and, as a rule, one of them was being selected. Thus, the statistical performance on each type of aircraft was becoming lower and lower while the attempt to use them to build a similar model inevitably led to a lag. It is necessary to emphasize the metaphysical nature of the statistical method which is based on cases that do not

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* For this reason, certain foreign governments were forced to cooperate in building aircraft (the Concorde, the A-300 Airbus, the Jaguar fighter, the Panavia-200 and others).

(1) Самолет	(2) Расчетное число M полета	(3) Взлетный вес самолета, Т	(4) Стоимость создания самолета, млрд. долл.	(5) Источник
(6) SR-71 (США)	3	45	1,0	Interavia, 1964, No. 5545, 5546
(7) B-70 «Валькирия» (США)	3	250	1,5	Flight, 1964, No. 2885, 2886
(8) TSR-2 (Англия)	2,2	45	1,0	Aviation Week, 4. XI 1963
(9) «Конкорд» (Франция — Англия)	2—2,2	175	2,8	Aviation Week, 1973, № 6

Key:

1. Aircraft
2. Estimated Mach number
3. Take-off weight
4. Construction cost, in billions of dollars
5. Source
6. (U.S.A.)
7. Valkyrie (U.S.A.)
8. (England)
9. Concorde (France-England)

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explain their nature and that do not take into account the interrelationships and interdependencies of all the aircraft's characteristics and their contradictory nature.

The optimal design method in aviation began to develop with attempts at an analytical, rigorously justified solution to the problem of selecting the most advantageous aircraft parameters and with attempts to eliminate the contradictions characteristic of aircraft parameters and performance.

N. N. Fadeyev's work, "An Investigation of Rational Aircraft Dimensions,"[8] was the first domestic work devoted to the optimization of aircraft parameters. Then, between 1940-1942, similar works appeared by other authors. From that time, the problem of criteria for evaluating aircraft became especially acute and important since optimization is not possible without criteria.

S. V. Il'yushin was one of the first designers to understand that it was wrong to simply evaluate aircraft according to their engineering statistics. As is well known, the IL-2 ground attack aircraft, which he conceived in the mid-30's and built in 1938, was not distinguished by high speed, long range or high altitude. The designer believed that the most important thing for a ground attack aircraft was its firepower and survivability. And, if it was necessary to sacrafice flying performance to achieve these new traits, then this had to be done. As far as speed was concerned, it was not beneficial to a ground attack aircraft; it was detrimental. According to S. V. Il'yushin's idea, the ground attack aircraft had to have the highest possible combat efficiency and the greatest probability of accomplishing its combat mission.

In the 30's, not enough people recognized that new aircraft traits were not "free" and that the inexhorable equation for the aircraft's existence*, which included all the component weights and flying performance, would require a cost in worse flying performance for firepower and armor. The designer had to solve the problem of compromising between weight and flying performance so that the aircraft's combat efficiency would be as high as possible. The IL-2 was undoubtedly not just the first effective ground attack aircraft but also the first aircraft in which S. V. Il'yushin implemented the principle of optimal design based on a single, comprehensive criterion--combat efficiency.

S. V. Il'yushin was the first aircraft designer to set out on the path of scientifically based methods for overall aircraft design; his practical work facilitated the introduction of a dialectical approach to defining the aircraft's configuration; with this approach, all aircraft characteristics, including the contradictory ones, were considered interdependent.

Certain military specialists did not understand S. V. Il'yushin's new approach to designing the IL-2 ground attack aircraft and they believed the aircraft was a failure based on its flying performance. The IL-2's employment in the Great Patriotic War demonstrated the aircraft's outstanding combat features. It was not the aircraft which was a failure but rather the criteria they tried to evaluate it with.

These criteria not only delayed the development of effective aircraft, as was the case with the IL-2, but they also provided an incentive for the appearance of aircraft which were subsequently rejected through practical experience. A high-speed fighter was designed at almost the same time as the IL-2. They had high hopes for it due to its superior flying performance: speed, altitude, etc. The fighter was developed based on the "war in the stratosphere" doctrine. However, practical experience demonstrated that the air war

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* This is what V. F. Bolkhovitinov called the equation for the aircraft's weight balance in the 40's.

of 1941-1945 was not in the stratosphere but primarily at low altitude. This fighter was not used very much at high altitudes and it was inferior to enemy fighters at low altitudes.

The American supersonic B-70 Valkyrie bomber met a similar fate in the 60's. This aircraft was designed for a speed of Mach-3 and an altitude of 20-25 km. But, after several aircraft had already been built, it was discovered that the "high-speed, high-altitude" concept was not effective. The "mistake" cost 1.5 billion dollars (see table).

It should be pointed out that S. V. Il'yushin did not retreat from the optimal design principle in his postwar design work. The parameters for each of his new aircraft (the IL-18, the IL-62 and others) were thoroughly based on the criterion of overall effectiveness; their operational environment and developmental prospects were taken into account. Therefore, it is not surprising that the IL aircraft have better weight efficiency, are more economical and are better adapted to modifications in comparison with similar aircraft.

As is well known, the aircraft is part of a combat or transportation system. Weapons systems and all types of airborne and ground-based equipment are being continually modernized in military aviation. In civil aviation, transportation volume is growing and requirements are increasing for transportation time, level of comfort and noise and reliability and economy. As a result of all this, the aircraft's design, parameters and performance must undergo fundamental changes over time so the system as a whole will have the highest possible effectiveness. This rather complex problem can be solved in two ways: 1) by replacing the aircraft fleet more frequently, or 2) by modifying the initial aircraft. At present, the first way cannot be considered efficient when you consider the colossal cost and extended developmental period for a new aircraft. It is more feasible to modify the basic aircraft by tailoring it to new operational environments.

The theory of modification, as part of optimal design theory, has recently been in the design and developmental stage. However, it is already clear that, while designing a new aircraft, the designer must show an interest in the most advantageous method for extending the aircraft's life via modifications to it and he must draw up a plan of the most efficient modifications over time.

S. V. Il'yushin played a large role in developing this theory. The aircraft developed under his leadership, the IL-4, the IL-14, the IL-18 and others, have had the greatest number of modifications compared to other domestic aircraft.

A characteristic feature of S. V. Il'yushin's design work is his interest in primarily obtaining the highest possible effectiveness for the aircraft system and his in-depth understanding of the interests of the government and nation.

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CHAPTER 15

THE IL'YUSHIN DESIGNERS

V. F. Leont'yev, doctor of engineering sciences and member of the board for the Ministry of the Aviation Industry

A lot has been written in various works and in this book about Designer-General S. V. Il'yushin's creative work and his aircraft, like the IL-2, the IL-4, the IL-28, the IL-12, the IL-14, the IL-18 and the IL-62, have gone down in the history of domestic and world aviation with gold stars. In this article, I will try to talk about the group which Il'yushin set up and developed, about its workstyle about the people who proudly bear the name of "Il'yushin designers" and about their subsequent work under a new manager.

Sergey Vladimirovich once said that it is incomparably more difficult to develop a capable group of enthusiastic people who think alike than it is to develop the best aircraft. This is indisputably true. Therefore, Il'yushin deserves a great deal of credit for establishing a group which can handle big jobs.

First, I would like to say several words about Sergey Vladimirovich Il'yushin himself; he had a long, difficult and remarkable life filled with searching and godsends, struggles and victories. It would be appropriate to remember the time when Il'yushin came into aviation.

Only the victory of the Great October Revolution made it possible for the son of a peasant to traverse the path from worker to designer-general and academician. As one of the stars in a galaxy of famous creators of Soviet aviation, he, like no other, was completely linked to the Communist Party throughout his life; he entered the party in 1918. Therefore, carrying out the missions assigned by the party became the meaning of his life, an inner need and his life had a sense of purpose. During the establishment and development of the Soviet state and during the first five-year plans, Il'yushin was among the ranks of the builders of a new society in our country (and one of the most talented aircraft builders).

Nature lavishly bestowed on Sergey Vladimirovich a rare talent and marvelous human traits. He was not only a talented designer and scientist but also a remarkable manager with the ability to instill enthusiasm in everybody around him. His enthusiasm and conviction, high principles and courage, humanity and rigor and the breadth and depth of his ideas not only brought him respect but also the true love of everybody who knew him and worked with him. Therefore, it is completely natural for Sergey Vladimirovich Il'yushin's colleagues and students to want to commemorate his precious nature and carve out a place for Sergey Vladimirovich in the history of Soviet aviation.

While talking about S. V. Il'yushin's place in the history of Soviet aviation, I am automatically struck by the persistence and steadfastness with which he proceeded toward his assigned goal because he recognized the country's need for aircraft. This was not an easy path. There is an element of luck in the fact that S. V. Il'yushin began serving in an Air Force unit at the end of 1915. But, while citing this and while saying that he was lucky, we can now assert that aviation was also lucky.

The very great importance aviation has in the national economy and in defending the country against all kinds of encroachments is now obvious and generally recognized. Moreover, the rapid annual growth in passenger and cargo transportation convincingly confirms this. But, this was not so clearly foreseen during the first years of the establishment of Soviet authority in our country. Aviation's role in the weapons arsenal was insignificant at that time. However, the technical feasibility of aviation made it possible for military specialists to hope that it would be employed on a more widespread basis in the future and that a formidable air weapon would be developed in the future. The young Soviet Republic did not inherit an aviation industry from Tsarist Russia. The production capacity of the prerevolutionary, semi-primitive aircraft plants was insignificant. Moreover, there was an acute shortage of aircraft specialists; many of them had sought refuge abroad.

It would be appropriate to recall that the aviation industry of Tsarist Russia produced extremely few aircraft and even fewer engines, primarily of foreign design; moreover, engine production actually consisted of assembling them from imported parts and units. At the same time, our country did have scientific personnel who were having a decisive effect on the development of world aviation. N. Ye. Zhukovskiy occupied a special place among the scientists. He not only founded aerodynamics but also developed an entire generation of Russian scientists, designers and engineers and established the Russian school of aviation. Our country can be proud of its capable, fearless pilots, including the famous P. N. Nesterov who was the first to develop the tactics of air combat, the principles of advanced acrobatics and the basic loop in 1913.

This difficult situation, which was exacerbated by universal disorganization, the destructive Civil War and, for all practical purposes, the lack of resources in the country, required the genius and farsightedness of the leader of the revolution, Vladimir Il'ich Lenin, who formulated our party's long-range policy in the field of aviation.

The party's policy for aviation anticipated: first, the top priority development of the domestic aviation industry in order to provide the country with the necessary quantities of military and civilian aircraft; second, the development of first class domestic aircraft by Soviet scientists and designers in order to free the country from its dependence on foreigners; third, the development of indigenous personnel to accomplish these missions by training Soviet specialists and by drawing the most devoted and talented scientists and engineers from the old school into the aviation industry. Based on the 28 June 1918 decision of the Council of People's Commissars, a decision initiated by V. I. Lenin, all the aircraft plants and repair shops in Russia were nationalized to accomplish the first task. But, this was the first step. The aviation industry had a large effect on many sectors of the national economy by levying requirements for various types of products; the state of the art of aircraft being built was dependent upon the state of the art in other industrial sectors. Therefore, to achieve success in the development of domestic aviation, it was necessary to develop the country's industries and to reequip a number of sectors.

In making the decision to develop domestic aircraft and aircraft engines, the party and government were relying on an increase in the state of the art for the basic industrial sectors. In this respect, the party's general policy of industrializing the country was the foundation upon which the swift development of the aviation industry was based.

In 1921, based on an order from V. I. Lenin, the Council for Labor and Defense established a commission to draw up a program for the development of domestic "aeronautics and aircraft production." In December 1922, a three-year program for reconstructing, rehabilitating and expanding enterprises in the aircraft industry was approved based on the decisions of the 11th party congress; this program was part of a 10-year program.

Few engineering sectors developed as swiftly as aviation, which played an important role in our country's defense and economy. This development was supported by continual attention from the party and government.

During the first years of Soviet power, the Moscow Aviation tekhnikum was established to train domestic aircraft specialists; it was subsequently reorganized as the Red Air Force Institute and later as the Air Force Academy imeni Professon N. Ye. Zhukovskiy. Many well-known designers, scientists, managers in the aviation industry and AF leaders received their higher aeronautical engineering education here. S. V. Il'yushin also graduated from the academy in 1926. The Air Force Academy and the Moscow Higher Engineering School subsequently formed the basis for developing a broad network of educational institutes and tekhnikums for training aircraft specialists in all fields.

The party, and V. I. Lenin personally, devoted a great deal of effort and attention to the establishment, consolidation and development of the aircraft industry's scientific and technological potential. After all, the technological state of the art for aircraft is, to a significant extent, dependent upon successful work by scientific research institutes and experimental design organizations. In December 1918, based on Professor N. Ye. Zhukovskiy's initiative and with V. I. Lenin's direct support, the decision was made to establish the Central Aero-hydrodynamics Institute (CAHI). The development of Soviet aircraft was underway.

Only a profound faith in the creative strength of the working class could explain this bold mission of building an industry with high engineering standards in Russia, which was backward and semi-impoverished at the time; the development of such an industry was only within the capabilities of the more technologically and economically developed countries.

Simultaneously with the construction of new enterprises to manufacture aircraft, engines, aircraft systems, airborne equipment and weapons systems in the 20's and 30's, scientific research institutes and experimental design bureaus were being set up and expanded. This made it possible to establish the necessary scientific and technological base and conditions which would not only make it possible to free ourselves from our dependence on foreigners but also to compete with the leading aircraft companies in capitalist countries. These were the design bureaus of A. N. Tupolev, S. V. Il'yushin, A. S. Yakovlev, A. I. Mikoyan, M. I. Gurevich, S. A. Lavochkin, N. N. Polikarpov, V. M. Petlyakov, P. O. Sukhoy, V. M. Myasishchev, G. M. Beriyev, A. A. Mikulin, V. Ya. Klimov and A. D. Shvetsov. With the participation of the scientific research institutes, they developed first-class domestic aircraft and engines. The Soviet Union had established its own aircraft industry. The results of our party's policy in establishing institutes, design bureaus, aircraft plants and in educating aviation personnel were not slow in taking effect. While evaluating the initial results in December, 1933, Comrade Ordzhonikidze, People's Commissar for Heavy Industry, said: "Several years ago, our aviation industry was completely dependent upon foreign equipment. We did not have any aircraft or engines of our own design. The situation has changed drastically now. We have first-class engines and aircraft of our own designs. We have a powerful aviation industry."*

Along with other designers, S. V. Il'yushin developed a winged tribe of Soviet aircraft which brought fame to our country. Each aircraft designer worked in his own field and designed his own themes. Thus, A. N. Tupolev's Experimental Design Bureau specialized in developing long-range, heavy aircraft while the basic theme of N. N. Polikarpov's, A. S. Yakovlev's, A. I. Mikoyan's and S. A. Lavochkin's design bureaus was the development of fighter aircraft. S. V. Il'yushin's interests were concentrated on the development of the basic types of aircraft: bombers, ground attack aircraft and airliners. His Experimental Design Bureau's success in each of these areas is well known. Each of the aircraft developed by Il'yushin's design bureau was creatively unique and represented an optimal combination of new elements for its time, elements which provided maximum satisfaction of customer requirements.

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* "Rech' pri otkrytii torzhestvennogo zasedaniya, posvyashchennogo 15-letiyu TSAGI" (Speech During the Opening Ceremonies for the Ceremonial Meeting Dedicated to the 15th Anniversary of CAHI), 23 December 1933, in "Articles and Speeches," vol 2, Moscow, Politizdat, 1957, pp 517-518.

Sergey Vladimirovich did not strive for external trappings; he developed aircraft which were "work horses" and "record breakers" at the same time. Altogether, aircraft with the IL trademark set 58 world records, including 10 in the CDB-26 (IL-4), 23 in the IL-18 and 25 in the IL-76. One of them made an historical flight from Moscow to North America. One of Il'yushin's first aircraft, the IL-2, played a prominent role in the Soviet Armed Forces victory in the Great Patriotic War. The group headed by S. V. Il'yushin achieved a great deal of success in developing civil aviation. The IL-12, the IL-14, the IL-18 and the IL-62 became the primary means of air transport in the USSR and they became well known beyond our country's borders; the IL-62 is the flagship of the Civil Air Fleet.

Presently, thousands of people and hundreds of organizations participate in the development of aircraft. The designer-general's mission is to integrate these efforts to achieve the assigned goals by using the latest achievements in science and technology; the group managed by Designer-General Il'yushin has designed original aircraft which readily reflect the creative influence of their developer.

Like the aircraft it designed, Il'yushin's design group had its distinctive features, which primarily included exceptional efficiency. The Il'yushin group has solved complex problems, usually with small numbers of highly skilled manpower; it has developed and is developing highly effective aircraft.

At the same time, the depth of their design analysis has made it possible to arrive at optimal solutions and to precisely forecast the final performance of the aircraft being designed. The latter fact has invariably led to a fit between actual and designed performance (this is how it was under Il'yushin and it has remained this way after his departure); it was not uncommon for aircraft to be delivered from tests with higher performance characteristics than those anticipated by the engineering requirements.

Another important consequence of their in-depth design analysis and precise, scientifically substantiated planning of all the processes of aircraft development was the efficient deadlines which usually made it possible to precisely calculate the time from the beginning of preliminary design to the aircraft's first flight. The recent, first flight of the IL-86 Airbus can serve as a confirmation of this.

High standards for weight factors were characteristic of Il'yushin's Experimental Design Bureau group; their aircraft were distinguished by their weight efficiency. The founder of the group also deserves a great deal of the credit for this. He instilled in each designer a recognition of the requirement for minimizing weight both while resolving problems in selecting dimensions and designing aircraft configurations and while designing parts.

The Il'yushin designers were trained in a spirit of high standards not only for weight efficiency but also for solving the problems of aerodynamics and strength, aircraft systems and components reliability, aircraft flight safety, economy and service life. Moreover, ensuring reliability and safety was and is the top priority concern during all stages of aircraft design, testing and operational use.

The Il'yushin group is characterized by a thirst for everything progressive and not just by introducing the latest achievement in the airframe and aircraft equipment. This group closely follows the appearance of new design methods, participates in developing them itself and widely implements not just new methods of design estimates but also experimental methods (for example, comprehensive bench work). The Experimental Design Bureau group is presently studying the problems of developing mathematical models for many of the processes in aircraft development where elements of automated design are used on a widespread basis.

Another area in the Experimental Design Bureau group's work should also be mentioned. Sergey Vladimirovich has always stimulated and supported all kinds of research and theoretical studies which are essentially a laboratory promoting the development of qualitatively new machinery. It is not by accident that the Il'yushin group has published an extremely large number of works, numbering in the hundreds, like no other Experimental Design Bureau. Many of these works are not only of practical value but also of scientific value and they are on the desks of designers in many organizations. This collective has a large number ot domestic and foreign patents for their inventions. Sergey Vladimirovich's successor is continuing to cultivate work on theory and inventions in the Experimental Design Bureau; like Il'yushin before him, he sees a great deal of benefit in this for developing new designs and he sees a remarkable school for the theoretical development of highly skilled specialists.

Sergey Vladimirovich and his student and successor are in the category of leader-managers which lead their groups. They demand creative people and not subordinates to carry out bold, creative plans. They not only expect implementation of the plan from them but creative, independent designs and brilliant job performance. The latter are rated highly by managers who give their assistants broad initiative in their actions.

Genrikh Vasil'yevich Novozhilov, a talented student of S. V. Il'yushin's, is presently managing the Experimental Design Bureau; two aircraft have been designed under his management. By building the IL-76 transport and the first IL-86 wide-bodied passenger aircraft, the new designer-general and his group again demonstrated their skill in developing effective designs. After all, the IL-86 was cited at the 25th congress as an example of superior scientific and technological efficiency.

In flying performance and specifications--which determine its economic efficiency, reliability and safety--the 350-passenger IL-86 Airbus represents not just a quantitative but also a new qualitative leap forward in the development of domestic airliner production.

This increase in efficiency was not only achieved by a sharp increase in efficiency compared to previous generations of aircraft but also due to a large number of progressive innovations in the aircraft's configuration, aerodynamic and weight design, development and technology and the use of new materials.

A reduction in the passengers' pre-flight and post-flight time was one of the design requirements for the Airbus. An original solution was found for this requirement in the design of the wide-bodied IL aircraft. The IL-86 differs from similar foreign aircraft in an extremely interesting innovation--built-in passenger ramps which make it possible for the passengers to disembark to the lower deck. Passengers who want to keep their baggage with them leave it there on the racks. The system of bringing your baggage on board does not preclude trips with checked baggage. For this purpose, the aircraft is equipped with baggage-cargo containers. Everything else in these aircraft is at approximately the same state of the art. True, the operational capabilities of the IL-86 make somewhat higher demands on airfields.

Not a single foreign wide-bodied aircraft has a similar baggage carry-on system. If the IL-86 is comparable to one of them in size and productivity, it is the L-1011. The per hour productivity of the IL-86 is somewhat higher since it carries a larger pay-load (42 tons versus 39 tons) at the same speed. Naturally, the IL-86's weight is somewhat larger than the L-1011's; this is not only due to its larger load-carrying capability but also due to the built-in ramps and universal baggage carry-on system. However, both the ramps and this system are undoubtedly good qualities in the aircraft.

In developing the IL-76 and the IL-86, the group and its new manager have protected and further developed Il'yushin's traditions, style and principles. Because of this, the aircraft are part of Il'yushin's spirit; the signature of Il'yushin's school can be seen in them. It is not by accident that the previous aircraft designation was retained in honor of the firm's founder and in honor of the group which bears the name of Il'yushin designers.

CHAPTER 16

SOME ASPECTS OF THE DESIGNER-GENERAL'S CREATIVE WORK

A. A. Maslennikov, design engineer

The aircraft designer's creative work has a lot in common with the creative work of artistic figures, especially architects and sculptors. Just like a work of art, an aircraft is always original and unique in some respect. This can be easily confirmed by conducting a comparative analysis of aircraft performance characteristics, their structural and design solutions and also by comparing the combined operational evaluations for aircraft and their overall appearance. The experienced aircraft specialists will always find signs which make it possible to identify the aircraft as belonging to a particular designer-general's school or to a particular aircraft firm. In contrast to the designer, the scientist, who is establishing the relationship between objective principles, can only express himself in his research methods. The laws of nature themselves are not related to the scientist's individuality. Regardless of the final result of creative work--a work of art, a scientific discovery or a new, original design--the basic idea is required to complete the event; the formulation of this basic idea is based on a forecast of the future role and performance of the aircraft. An intuitive idea of the future aircraft's configuration, its shape and dimensions was the primary problem for aircraft designers in the 20's through the 50's; their individuality was most vividly displayed in solving this problem. S. V. Il'yushin undoubtedly had the ability to intuitively conceptualize the optimal configuration of a future aircraft without conducting voluminous estimates and studies.

Not all promising ideas can be implemented within established deadlines. Therefore, a realistic approach to solving assigned problems, which consists of correctly evaluating engineering capabilities, is the most successful path for the aircraft designer.

The implementation of the basic idea is always related to numerous subsidiary problems which must be thoroughly studied during the early stages of design work in order to obtain complete confidence in the feasibility of their implementation. S. V. Il'yushin always formulated the goal of aircraft development and he anticipated performance characteristics precisely and clearly and guaranteed construction within the shortest possible deadline. Sergey Vladimirovich kept his promises. This was explained by his surprising foresight which was based on the in-depth analyses which he personally conducted, on scientific and technological achievement and on systematized experience.

Numerous examples can be cited when S. V. Il'yushin, after protracted and even distressing vascilation, refused to use extremely tempting systems--which were promising at first glance--in an aircraft's design. This is specifically what happened with the proposal to use a power-assisted control system on the IL-62. One of the possible designs of such a control system was tacked to the wall in Il'yushin's office and hung there for approximately a year. He returned to review this design on numerous occasions before he finally set it aside. The use of a power-assist on the IL-62 violated the basic idea for the aircraft--design simplicity and operational simplicity.

A significant feature of the aircraft developmental process consists of the fact that creative work continues after it is built, debugged, tested and put into series production and during its operational use. This final stage of the designer-general's work is perhaps the most important; it continues for years and sometimes for decades and it includes the development of aircraft maintenance systems, training flight personnel and ground crews, establishing the actual reliability of all aircraft systems, determining the safe service life, making improvements to enhance safety and overall aircraft life and, finally, modernizing the aircraft design in accordance with operational requirements.

S. V. Il'yushin considered the development of aircraft systems and parts which were easy to produce and reliable in operational use a problem of top priority importance. He spent a lot of time working with his designers to achieve the best solution; he took pride in structural elements and systems which were done well and he used them in many types of his aircraft.

Sergey Vladimirovich devoted special attention to aircraft in operational use; he personally inspected maintenance methods at the airfield: accessibility during inspections, the possibility of mistakes appearing, etc. He frequently talked to aircraft maintenance technicians and pilots and thought over their critical comments which he believed were the designer's pot of gold.

The appearance of jet engines opened up enormous possibilities for designers to obtain high speeds but it also created new problems. One of them was the problem of engine location. with his characteristic perspicacity, Sergey Vladimirovich installed wing-mounted engines on the new bomber model. This jet engine configuration was on the IL-22, the IL-46 and the IL-54 bombers. It was subsequently used on numerous aircraft.

Sergey Vladimirovich always attached a great deal of importance to the job of defining the overall configuration for future aircraft and he devoted a lot of time to it. He personally participated in drawing up alternative aircraft outlines and this gave him the opportunity to compare aerodynamic configurations and also combat and operational effectiveness. Small, wooden models were made of the most promising versions; this made it possible to study the aircraft's streamlining in an airflow and to evaluate the proportions between the size and load-bearing design.

There were cases when S. V. Il'yushin's aircraft designs encountered critical comments from management and customers who did not sufficiently understand the merits of the designer-general's plan. They attempted to make changes in the design and to convince him of the feasibility of their suggestions which violated the basic idea. In these cases, Sergey Vladimirovich told them: "You don't need this kind of aircraft" or to preclude starting an argument: "We don't have that kind of aircraft." Pressure from management or persuasion from colleagues usually did not help. A high standard of principles based on deep conviction was one of the basic, characteristic features of S. V. Il'yushin's creative work.

At the end of the 50's, the designer-general was considering the possibility of developing a supersonic airliner. Establishing the flight speed, preventing structural heating, selecting the material for the structure--duraluminum or steel--noise, comfort, operational and safety problems--all of these were the subjects of studies and analyses. Sergey Vladimirovich understood that it was premature to extend work on developing such an aircraft on a widespread basis. The state of the art in industry and operations still did not make it possible to build a supersonic aircraft that was as safe and efficient in flight as a subsonic aircraft. S. V. Il'yushin's prognosis was brilliantly confirmed ten years later when the Boeing Company stopped development of a supersonic airliner for the same reasons after developing a detailed design.

There are numerous examples in the history of science and technology where the "prophesies" of talented engineers, designers and scientists, prophesies based only on intuition, have made it possible to guess the future path of engineering development rather accurately. The creative work of S. V. Il'yushin is a good example which confirms this proposition. However, the cost and time periods involved in developing aircraft have increased so much in the last two decades that it has become too risky to just rely on the designer-general's intuition and talent. The modern science of forecasting advances a number of methods for short-range and long-range forecasts. An analysis of present conditions, statistical collection and processing with modern mathematical methods combined with stochastic approaches make it possible to make a rather realistic forecast of the configuration and performance requirements for future aircraft.

The flow of passengers between populated areas, the operational environment and the competition from other types of transportation are being studied. The development of populated areas linked by air routes and the probability of changes in the passenger flow are being taken into account. For forecasting purposes, characteristics which do not become less important over time are being thoroughly selected.

It is a difficult task to incorporate the idea for future aircraft in the blueprints and to ensure a high degree of quality in manufacturing it without violating the general-designer's plans. This problem can be solved if the design is developed on clearly expounded principles. S. V. Il'yushin levied strict requirements on his colleagues to comply both with generally accepted design rules as well as those formulated by them. He was especially persistent in implementing the principles of few details, "direct perception of strength" and "human capabilities" in the Experimental Design Bureau's practice. The design principles and rules developed by S. V. Il'yushin established a special style in the design of his aircraft which have a high degree of efficiency and production quality. This style will undoubtedly be incorporated in the designs of new aircraft built by his Experimental Design Bureau and it will be improved by taking the new achievements in science and technology into account.

CHAPTER 17

SON OF THE PEOPLE

V. I. Yegorov, design engineer

On numerous occasions, Russia has presented its sons to the world, sons who, out of the depths, have left the plow, the ax and the hammer to take their place in the top ranks of scientists, engineers and artists due to their ability, talent, will, persistence and sense of purpose. The man whose name has been carried around the world on hundreds of silver airliners and formidable combat aircraft can rightfully be included among them. This man is Sergey Vladimirovich Il'yushin, thrice-honored Hero of Socialist Labor, Lenin and State Prize Winner and full member of the USSR Academy of Sciences.

What was the path taken by Vladimir Ivanovich Il'yushin's 11-year old son, Serezha--who was born on 31 March 1894 in a peasant family--before he became a prominent aircraft designer and the founder of a universally well-known school of aircraft production?

Serezha learned to read at the age of six and entered the county school at the age of nine. He took to reading at school and frequently, when his friends were running through the fields and glades, he sat by the school bookcase selecting books in his favorite subjects--mathematics, geography and Russian. Sergey Il'yushin began his work career early: at 15, he was hired as an unskilled worker at a factory in Kostromskaya Guberniya. The contractor said: "You're not very big, but you're strong." And he hired him. This strength was useful to Sergey since the job as a loader was hard and, by evening, his arms hurt unbearably and his entire body was leaden.

Sergey Il'yushin saw a lot of places: Peterburg, construction of the Amur Railroad, Revel'. He held various jobs: he cleaned out gutters, was an unskilled laborer, a grease monkey, a time keeper, a stoker and a mechanic's helper on one of the first Russian excavators. During all these years, books traveled with him.

He always investigated the surrounding world attentively, tasting the unknown and trying to draw new things from the people he encountered by fate.

While working as a ditch-digger at Peterburg's Kolomyazhskiy Hippodrome, which was being transformed into a flying field for the occasion of the first aviation week, Sergey and the others dug holes and cut patches of grass. Later, he helped load large crates and helped assemble the aircraft. He could hardly believe that these strange structures, which resembled shells, were able to fly and soar in the air like birds, responding to man's will.

This was the remarkable time of the first flights, if those short runs and awkward hops, which these "flights" frequently ended in, can be called that. It is doubtful that anybody in the crowd which filled the Kolomyazhskiy Hippodrome during those days paid any attention to the enthusiastic light in the eyes of the small boy in the high-collared Russian shirt. But, many years later, Sergey Vladimirovich Il'yushin would say: "It was then that my love for aviation appeared."

It was the First World War. After being drafted into the army, Il'yushin, as a man with an education, was assigned as an assistant clerk with the Vologda military commander's detachment. But, the job of headquarters clerk was not for him. There was a lucky break and Sergey was assigned to the airfield detachment at Peterburg's Kommendant Airfield Amongst so much which was unknown and attractive, the young soldier was always ready to clean the hangars, roll out the aircraft and wash them if only he could stand alongside them and he was always ready to help take them apart if only he could have the opportunity to ask the specialists detailed questions about their construction. His curosity was noticed and three months later Il'yushin was assigned as an engine specialist. The aircraft were closer and more accessible. But, the idea of flying on his own did not give him any rest. When, during the height of the war, permission was granted to enroll representatives from the "lower classes"--rank-and-file soldiers and workers--in flying schools, Sergey achieved his wish. In the summer of 1917, he became a pilot.

Now that his dream had come true and he realized that his life would be devoted to aviation from now on, his desire to study was even greater.

The October Revolution opened up the path to an education, to science, for Il'yushin; it rang in the beginning of a new era, an era of the people's power, the power of the Soviets. "I had no problem deciding who to go with. The Soviets were my own authority," Sergey Vladimirovich has said. He was in the thick of things from the very first day; he was elected to the airfield's revolutionary committee and he was responsible for protecting the aircraft for the developing detachments of the Red Air Force. Il'yushin has been in the ranks of Lenin's party since 1918.

Upon returning to Vologda, the engine specialist from the Red Army's Peterburg unit was put in charge of the Vologda Soviet's Industrial Department; he coordinated the work of the nationalized factories and plants and did party work.

In May 1919, he was in the Red Army again, on an aircraft repair train for one of the Northern Front's armies. Out of ten aircraft put out of commission, they assembled one or two aircraft which were more or less suitable for flying.

Once, the news arrived that a shot down White Guards aircraft of a new design had landed in the deployment area of Red regiments. Sergey Il'yushin and five Red Army soldiers made their way through the woods to the landing site, disassembled the aircraft, carried it to the railroad station and delivered it to Moscow.

After the Northern Front, he was assigned to Saratov, the aircraft depot for the Caucasus Front. Under difficult conditions, Commisar Il'yushin and his comrades restored the Farmans, Newports and Havillands here.

In 1920, the Red Air Force Engineering Institute imeni N. Ye. Zhukovskiy was established and, in 1921, Il'yushin became a student at the institute.

Sergey Vladimirovich rapturously studied many subjects, especially higher mathematics. When the institute was changed to the Air Force Academy imeni N. Ye. Zhukovskiy in 1922, the mathematics course was repeated and Il'yushin attended the entire course again. "It did a lot for me," he recalls. "I might even advise future designers to do the same thing."

The curriculum which the first engineers in Soviet aviation studied was developed by N. Ye. Zhukovskiy. It made high demands on the students and it provided the basic knowledge in many areas related to aviation. B. N. Yur'yev and V. P. Vetchinkin conducted the basic subjects brilliantly. A lot of attention was also devoted to practical training. Studying was easy; Il'yushin sat over his books day and night.

During these years, the country was laying the foundation for its future aviation industry by aggressively recruiting talented young people for this important job. The slogan appeared "From the Model to the Glider; From the Glider to the Aircraft." Sergey Vladimirovich was also captivated by gliding. Gliding gave him an opportunity to gain personal experience in design work and to test his budding ideas. At the same time, work in gliding provided a broad field of social activities. Communist Il'yushin understood that the party was following a policy of developing an air force and that this task could be accomplished on an accelerated basis by attracting large groups of young people to flying sports. He became an active participant in the academy's glider association and he organized associations at the Mastyazhart Plant and at the Transportation Institute; he disseminated knowledge about aircraft among Moscow's workers and students.

In 1923, Il'yushin developed his first design--the Mastyzahart light training glider--and he participated in the First National Glider Pilot's Meet in the Crimea, near Koktebel'. On 10 November, the Mastyazhart flew for the first time. After taking off, it made a short flight and...dropped. This was his first lesson in applied air flow mechanics; the aircraft's center of gravity was not right. But, the pilot was not harmed and the glider could be restored (such miracles also occurred at the front lines). His debut was completely successful: Il'yushin's name was among the prize winners for the first glider competitions.

Dozens of different designs soared over the sunburned slopes of the Crimea; bold ideas and design methods were being tested here; there were heated arguments on the ways to develop aviation. To gain an understanding of the atmosphere at these meets, it is enough to mention just some of the participants: V. S. Pyshnov, B. T. Goroshchenko, M. K. Tikhonravov, O. K. Antonov, S. P. Korolev and A. S. Yakovlev--future scientists, aerospace designer-generals and leading test pilots.

Here is how O. K. Antonov recalls one of the episodes in his life: "I was on night duty for the meet... It was quiet. Like enormous wedges, the long, narrow wings were criss-crossing the shadows in all directions, the shadows of the small mountain ravines with the still gliders at their edges for their short night's rest.

"Our City of Lenin is below me, about 20 paces down the slope. Beyond it is the Skiff, Komsomol Truth, the Gamayun, the Stamp, the Breeze, the Red Star, the Old Man, and many, many others.

"Further on, there was a large canvas tent-workshop, a plowed strip, slopes and the endless steppe.

"Suddenly, the thoughtless chirping of the crickets was broken by a completely different, troublesome, rhythmically increasing noise. It was a vehicle. The headlights were shining. The vehicle stopped near the tent. A man got out of it. He headed toward me. Of course, it was one of us, but who? I waited.

"The not-quite distinguishable but very familiar figure approached, stopped and was evidently trying to get its bearings in the dark among the camp's winged chaos. Then, evidently finding what he needed, he decisively set out for our City of Lenin, circled around the glider and stopped by the tail, lightly pushing the verticle stablizer with his outstretched arm. The stablizer was braced to the wing by four thin, steel guywires and it did not give to the pressure.

"The figure pressed it harder. A clasped guywire gives off a bass note.

"Aha! This is Sergey Vladimirovich Il'yushin, the well-known aircraft and glider designer and chairman of the meet's Engineering Committee!

"Now I remember the heated discussion in the Engineering Committee during the day: was the tail section on our glider fastened rigidly or loosely. Could the tail section be attached to a long boom with a small cross-section, which only deflected in the vertical plane and which was only kept from twisting and turning to the side by four thin guywires running to the rear wing spar? They argued about it, went on to other problems, argued about it again, and evidently, on the way from the camp to Koktebel' and, finally, after the next especially heated flare-up in the argument in the evening before the chairman of the Engineering Committee arrived at the camp, he came to the City of Lenin's stabilizer.

"Sergey Vladimirovich stood near the stabilizer as if he were evaluating it and thinking it over. His entire body expressed a sort of illusive degree of consternation and disagreement with the evidence of his direct and immediate experience. But now, after apparently weighing something, Sergey Vladimirovich decisively put his shoulder against the upper stablizer unit. He shakes the guywires again. This time, the wing raised toward the sky swayed from the decisive jolt. He thinks it over. Turns. And, with the characteristic gait of a strong-willed person who is thinking something over on his way, Sergey Vladimirovich returned to his vehicle. The engine sputters, the car goes into reverse, turns and, with the yellow beams of its headlights fanning over the camp, it disappears behind the hill just as suddenly as it appeared.

"...The next day, with authorative pressure from the chairman of the Engineering Committee, our long-winged City of Lenin was given the green light to go into the wild blue yonder."*

The work on the gliders and the flights in them gave the future aircraft designer a lot of experience. "For the aircraft designer, gliding is the cradle which the child should be rocked in before he learns to walk," said Sergey Vladimirovich.

In 1926, after defending his dissertation, S. V. Il'yushin was awarded the title of military mechanical engineer in the Air Force.

The assignment he received after that was an honorable and responsible one--managing the first section of the Air Force Technological Committee, the section which established the requirements for combat aircraft. Four years of working in this post made it possible for Sergey Vladimirovich to get to know the creative methods of aircraft designers, gain an understanding of the production process at aircraft plants and get acquainted with various military doctrines and special features of military aircraft combat employment. Heated arguments frequently flared up between customers and manufacturers at committee meetings and, as AF LtGen N. Sokolov-Sokolenok recalls, "Il'yushin's precise engineering estimate" always "served as a cold shower."

After his work on the AF Technological Committee, he was transferred to the position of assistant chief of a Scientific Research Institute, to the management of an CAHI Central Design Bureau later and, finally, to the management of the Central Design Bureau for the Plant imeni V. R. Menzhinskiy, which integrated the design groups of N. N. Polikarpov, D. P. Grigorovich and S. A. Kocherigin.

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* O. K. Antonov, "Ten Times at First," Moscow, MOLODAYA GVARDIYA, 1969.

No matter where the party sent him during all these years, Sergey Vladimirovich worked at full steam everywhere, by continually studying, expanding his horizons and analyzing the experience of domestic and foreign aircraft production. The more knowledge he obtained, the more enticing the idea became of doing his own, independent design work and of getting a group which he would be able to rely on in the difficult job of developing aircraft. Il'yushin sent report after report proving the feasibility of his work at the blueprint table and he got his way; 1933 was the year that a new group was born, a group which brought its own characteristic Il'yushin signature into aircraft production. From that time on, he was a designer.

"The designer-general knows the aircraft better than everybody. He has more responsibility for it than anybody else. This is not just an honor, this is his responsibility to the country and people," said Sergey Vladimirovich. Being a designer-general means sleepless nights and protracted meditation in selecting the best alternative; it is the knowledge and ability of being able to single out the top priority from the secondary; it is a talent for finding a simple solution to complex problems; it is inflexible will power.

The first aircraft built under his leadership, the CDB-26, made him famous--five world records were set in it. During the work on this aircraft, the expertise of Il'yushin and his group of enthusiastic, single-minded designers began to be perfected; he had carefully molded this group by instilling high principles, intellectual courage, strong will power and a thirst for a continual search for knowledge in them. "If you don't learn anything in the course of the day, consider the day lost," Sergey Vladimirovich frequently told them.

The international environment was becoming more and more tense and Sergey Vladimirovich returned to the idea of developing a ground attack aircraft--a direct battlefield support aircraft. He had to have confidence in his own capabilities and be convinced that he was right to send a letter to the government requesting that he be assigned the job of developing a ground attack aircraft: "The task...is exceptionally difficult..., but I will enthusiastically undertake this job with complete confidence in its success."*

Again, there were days and nights of searching and of intense work for the group; S. V. Il'yushin was the soul of this group. He found time to go everywhere: he convinced the military, kept pestering the main committee and flew to the plants

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* See p. 160 in this collection.

(this is where his ability to fly an aircraft came in handy) which were producing components of the future aircraft.

The ground attack aircraft was ready in 1938. This was an enormous victory for the designer and the group he was in charge of and it was a victory for Soviet science and technology. The armed forces received a formidable military aircraft.

The Great Patriotic War was under way; the IL-2 became the "black death" to the fascists. The designer and his group did everything possible to improve the IL-2 and to provide the front with more aircraft. The design bureau had been evacuated; it was accommodated in a two-story bookstore where they put in desks in place of the shelves. "We worked as though we were possessed. We slept and ate right at the design bureau," recalled Sergey Vladimirovich. Production was proceeding under the most difficult conditions; the wing of the plant which was producing the IL-2 did not have any wings; but, in spite of the icy cold and snow storms, the shops began their work on schedule. Old people, women and children were working at the machine tools. The designer-general's presence inspired them; it gave the young trade school students--who had to stand on crates to reach the machine tools--strength; they were going hungry and working double shifts.

Sergey Vladimirovich gave his all to the job: he met with the front line pilots, listened to their common sense suggestions and had time for the forges and shops. Under the most intense work conditions and deprivations, a special atmosphere of efficiency, devotion to their work, friendship, a readiness to support each other at any time, to share their rations and to encourage each other with a warm word developed within the group of Il'yushin designers. This, in turn, gave Sergey Vladimirovich new strength. "After all, it is a great joy to go to work when you are surrounded by friends and comrades," Il'yushin once said.

The war had died away, the vultures were wiped out of the skies of our motherland and the designer-general was occupied by new thoughts. "To put as many people as possible on an aircraft,"--this was Il'yushin's new program, his new goal which he set for the group. He set it and successfully accomplished it by giving our domestic air fleet the IL-12, the IL-14, the IL-18 and the IL-62 airliners. A single continent probably cannot be found in the world where aircraft with the letters IL on the side have not been.

In his life, Sergey Vladimirovich had a single, "ardent desire"--to develop and modernize aircraft. Days and nights of tireless, purposeful searching were devoted to this job. His main character traits were formed and developed during this work: a sense of purpose, will power, the ability to think accurately, composure, a colossal capacity for work, kindness, understanding and high principles.

The lights in the windows of the designer-general's office went on earlier and went off later than in all the other offices. The first half of the day was only for creative work, among the design teams, at the estimators desk and in the shops. Sergey Vladimirovich could approach anyone; he knew everyone and he knew each person's work. At the short, businesslike meetings which gave a clear idea of future plans, Il'yushin primarily demanded inner conviction from each person who spoke: "Only then can you convince other people." Composed, polite and correct and he demanded the same from his subordinates. No loud "dressings down" but, if Sergey Vladimirovich did not address his closest assistants on a first name basis, everybody knew he was dissatisfied.

Modesty was another of Sergey Vladimirovich's typical traits. Reporters came to the Experimental Design Bureau on numerous occasions; numerous articles appeared in the press. Il'yushin was able to talk for hours about aircraft and about the prospects for aviation development. But, he did not like to talk about himself. "The aircraft sing the designer's praises in the skies,"--these were his words.

Along with his enormous, truly gigantic work in developing aircraft, Sergey Vladimirovich was widely involved in public affairs. He was a deputy to the USSR Supreme Soviet, a permanent member of the Experimental Design Bureau's party bureau and a teacher. He received visitors and letters. Everybody obtained advice, a kind word and support from him.

When he arrived at the Academy imeni N. Ye. Zhukovskiy, S. V. Il'yushin sat down at the draftsman's desk with detailed blueprints and would spend hours analyzing dissertations and talking to students as equals. Attentively, politely and without the slightest reproach, he trained the young engineers who arrived at the design bureau from the institutes. "Our conversations with Il'yushin helped us a great deal," recalls G. V. Novozhilov, designer-general and S. V. Il'yushin's student and successor. "What we obtained from them helped us gain an understanding of the inner mechanism of the aircraft designer's skill, his frequently deeply hidden rules," which were accessible to a talented, analytically minded man.

Il'yushin's selection as a full member of the USSR Academy of Sciences and the award of the Gold Medal to him by the Federation of International Aviation were in recognition of his creative successes.

Sergey Vladimirovich gave all his efforts and all his time to his favorite job; but, at the same time, he always found an opportunity to take a breather, to toss out a joke and lift his eyebrows in a rouguish glance--after this, things were lighter and there was added energy. On a holiday evening, he could win the prize for waltzing, find some time and go to the Bol'shoy Theater to watch the ballet. At his summer place, he trimmed the apple trees himself and always brought out something wild and, as always, got carried away by the creative process. At home, he had an accordian he designed; after tuning it, he liked to relax by playing the lingering melodies of the North.

Il'yushin usually spent his vacation in his home town in Vologodskiy Kray. "Kubenskoye Lake is near us there. It has a lot of small islands and marvelous hunting! Sometimes, I'll build a sort of lean-to on one of them and settle in with my gun and rod and reel. This is the best relaxation for me after all the constant activity at the design bureau and the hubbub of Moscow," Sergey Vladimirovich said. The designer-general returned to the design bureau relaxed, renewed and with such a store of energy that he could move mountains.

On a January day in 1977, a bust of Il'yushin was erected here, in his native area, in one of Vologda's central squares.

It was noon. Large flakes of snow were softly settling on the trees, on the shoulders of the people gathered there and on the cloth covering the bust. Solemn tunes could be heard. There was a sense of warmth, sincerity and gratitude in the speeches made by numerous orators. Finally, the cover fell away and all those present could see the image of their countryman, S. V. Il'yushin, one of the most talented aircraft designers, whose life and work was a vivid example of endless service to the working people, his native land and the Communist Party.

PART II

SELECTED ARTICLES BY S. V. IL'YUSHIN

CHAPTER 18

IL AIRCRAFT SERVING THE MOTHERLAND*

This brief historical survey of our group's creative work was written at the request of the editors; it has not been written in a strict chronological sequence. I believe it is advisable to review our work in the development of three categories of aviation: ground attack, bomber and fighter. Each of these categories includes a large number of aircraft types. The total number of IL aircraft built has reached 57,000.

From the first days of its existence, our design bureau's practice has been based on five basic directions which cut through all the stages of planning and design, beginning with preliminary studies. These areas include: a desire to achieve maximum combat effectiveness or commercial efficiency, superior reliability and safety, technological effectiveness and simplicity. Moreover, we have striven for simplicity in all our design solutions which ensure simplicity in production, handling and operational use. It is well known that an aircraft, especially a modern one, is an extremely complex machine which is described by a significant number of different parameters and which is equipped with a large number of different kinds of equipment. Therefore, it is natural that a high degree of effectiveness is established for it by solving not only design problems but also numerous scientific and technological problems. One of the primary ones, and frequently decisive ones, is the problem of overall aircraft size. We have always tried to develop the minimum size aircraft for the given combat effectiveness or commercial productivity. A great deal of

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* Published in AVIATSIYA I KOSMONAVTIKA 1968: No 5, pp 10-12; No 10, pp 32-37; 1969: No 5, pp 44-47; No 6, pp 33-37.

experience has confirmed the rational basis for this course. Our group has been able to develop aircraft which are significantly smaller in size and tonnage than the aircraft of other groups, of course, with the invariable condition of accomplishing equivalent missions. This constant trend toward minimal size can be traced both in the development of ground attack aviation and in bomber aviation.

The aircraft's aerodynamic configuration is another decisive problem and we devote an exceptional amount of attention to its solution. Widespread aerodynamic studies have led us to a number of interesting solutions. For example, due to the aerodynamic configuration of the IL-28, with its unswept wing, the aircraft has high-speed performance characteristics which are almost as good as the performance characteristics for swept-wing aircraft.

We are also working just as energetically to develop and improve efficient wing high-lift devices--single and double-slotted flaps, inteceptors, spoilers (which we have been using for a long time) and also original designs of ailerons.

Our efforts to achieve the best stability and controllabilty were not only successful on aircraft like the IL-28 but also on our largest airliner, the IL-62, where the wing has a 35 degree sweep and the tail section is T-shaped. If the advantages of this wing are not viewed in isolation but are studied as a combination of wing and tail section, aerodynamic efficiency and stability characteristics and not forgetting the interrelationship between aerodynamics and weight, then it turns out that the IL-62's aerodynamic configuration is close to optimal. At present, it is difficult to propose any kind of new wing which would bring about an overall, noticeable improvement in the aircraft, i.e., a wing which would not lead to a noticeable degradation in other parameters while improving some of them.

All of the enumerated trends are closely interrelated. Thus, highly efficient aircraft, whether they are ground attack aircraft, bombers or airliners, have invariably been built at many factories and have entered operational service in large numbers. This fact levies rigid requirements on the technological effectiveness of the design, handling simplicity and ease of ground servicing. As a result of this, technology has to be approached on a broad scale. For example, during the development of the totally armored ground attack aircraft, there was a critical problem of stamping curvilinear (with a slight camber radius) sheets of rigid steel armor which were thick enough. Another example was the first domestic jet bomber, the IL-28, which was put into mass production at many plants.

To significantly expand the amount of work being done simultaneously, we developed and patented a new process for assembling the wings, tail sections and fuselages which were structurally cut along the horizontal axis. Thus, each of these aircraft components was made from two half sections. This structural division not only significantly expanded the amount of work being done simultaneously but also reduced the labor intensiveness. This solution was achieved at low cost--the structural weight was increased by a total of 1.5 percent of the empty aircraft weight. Using large-scale, integral, machined panels in the design of the wing, fuselage and tail section, using the wing as a fuel container instead of tanks and other similar steps not only reduced the aircraft's structural weight but also simplified the production process in the final analysis.

The principle assumption in our creative work was an orientation on the latest achievements in science and technology. Therefore, as a rule, new engines and new equipment systems are developed for newly designed IL aircraft. This progressive method--the method of minimum continuity in solving cardinal problems--makes it possible to develop promising aircraft which are competitive throughout the extended period of their operational use. The longer periods of time required to design and test new equipment in this case are subsequently paid back with interest.

Consequently, our group is continually searching for new solutions which are made on the basis of comprehensive theoretical and experimental justification. As already mentioned, we attach the same degree of importance to the simplicity of our solutions. After all, it is well known that it is the simple which is the hardest to develop. By developing simple designs, we are training masters of simple solutions.

We try to achieve the ideal aircraft which is characterized by the best performance of its role, i.e., we try to achieve the highest combat capability for military aircraft and maximum productivity for civilian aircraft. Only aircraft which are completely accomplishing their missions can remain in production and operational use for an extended period of time. The development of these aircraft is based on thorough design work, testing and production.

Thus, aircraft design is a multi-faceted creative process which encompasses a broad group of problems ranging from the purely scientific to practical ones. An optimal solution to these problems makes it possible to develop truly high-volume transportation equipment and reliable weapons systems for the air forces, equipment which is as good as the foreign state of the art and frequently outstrips it.

/Ground attack aviation./ It should be pointed out that the idea of ground attack aviation was born in Russia in 1912-1913 when attempts were made to develop an aircraft with weapons designed to strike ground-based targets and with a cockpit protected by armor from the bottom. In 1913, tests were conducted on firing a machine gun from an aircraft against ground-based targets. The same kind of tests were conducted abroad much later. For example, they did not get underway in the U.S. until 1927. The attempt made in Germany to convert the Junkers J-1 for ground attack operations was not successful; after this, they did not attempt to develop this kind of aircraft abroad.

In the 30's,work was underway in the Soviet Union to design an aircraft with this kind of role but a low-altitude aircraft with the required performance was not obtained at that time. Actually, it was not easy to forge an aircraft in armor with minimal waste in the margin of weight which was so necessary to equip the ground attack aircraft with bombs, rockets, cannons and machine guns. The problems of making trade-offs--between size and weight, speed and maneuverability, flight performance, bombing-gun weapons systems and armor--were also not easy. These difficult problems were solved with the development of the world's first ground attack aircraft, the IL-2; design work began on it in 1936 and it was tested in 1938-1939.

An armored hull which protected all vitally important aircraft components was designed: the engine, the crew cabin, the oil and fuel systems and also the engine water cooling system. The hull was given a streamlined shape in spite of the technological difficulties of stamping thick armor. For the first time, armor was included in the load-carrying design of the fuselage and maximum use was made of its strength characteristics; minimal weight was achieved by an individualized arangement of the armor, i.e., by distributing various thicknesses along the surface of the hull with consideration for offensive and defensive tactics.

Other problems which were perhaps just as difficult were: developing an aircraft with a large speed envelope and achieving high maneuverability for the maximum speed possible at that time. These problems were solved by carefully selecting the aerodynamic configuration for the wing based on a comprehensive analysis and experiments.

The solution to the engineering problems of developing a ground attack aircraft and tactics for employing it was made more difficult due to the fact that many specialists misunderstood the importance of this type of aircraft. At first, the problem of choosing the number of crew members and defensive weapons in the rear of the fuselage turned out to be controversial. We were convinced that the aircraft needed a gunner to defend the rear hemisphere. Consequently, a two-seat prototype was built. But, they did not agree with us and a single-seat version was put into series production. Jumping ahead somewhat, it should be mentioned that the front line pilots supported our point of view and we returned to the two-seat configuration during the war.

As a result of the same underrating of our aircraft, it went into series production late. Series production began after a delay of an entire year and the scale of series production was far from sufficient. As a result, there were extremely few of the IL-2's by the beginning of the war; but, later, production was expanded and ground attack aircraft assisted in routing enemy tank formations during the counteroffensive at Moscow (in the winter of 1941).

With the AM-38 engines designed by A. A. Mikulin (maximum take-off power of 1,760 hp), the IL-2 developed a speed exceeding 400 km/hr at a range of approximately 800 km; its take-off weight was 6,360 kg with an empty weight of 4,530 kg.

The party and government believed that it was very important to develop mass production of these aircraft. Three of the highest capacity plants, which produced over 40 aircraft per day, were allocated to produce the IL-2. The telegram to the plant directors, which provided the instructions to urgently speed up the program, stated that the IL-2's were as necessary to the Red Army as air and bread. In the history of aviation, a record-breaking number of IL-2 and IL-10 ground attack aircraft were built--over 41,000 aircraft. This figure testifies to their efficiency and their role during the war.

In order to gain a complete idea of the ground attack aircraft's importance, it is necessary to add their exceptional reliability and survivability to their flying performance, combat performance and numbers. The IL-2 went through several changes in engines which extended their service life and it went through a large number of sorties. Damage to the wings, aft section of the fuselage and tail section did not prevent the IL-2 from returning from its home base.

The aircraft remained operational and continued to fight; this was facilitated by the skill and heroism of Soviet ground attack pilots. This reliability and survivability resulted from an optimal combination of aerodynamic configuration, flying performance, stability and controllability, excess engine power and an efficient armor arrangement for all vitally important aircraft components.

The Germans attempted to design and build an armored ground attack aircraft like the Soviet IL-2 during the war but they were not successful. Thus, the Henschel Firm designed an aircraft--the HE-129 "tank destoryer"--armed with a 30-mm cannon. But, this attempt failed. During the war, our ground attack aircraft carried out the most diverse missions: they destroyed enemy columns and did not permit him to regroup and consolidate his forces; they destroyed bridges and river crossing sites while interdicting planned enemy movements; they destroyed his manpower; they suppressed ship's artillery and frequently sank ships; and they destroyed motor vehicles and railroad stock.

The ground attack aircraft bombed targets both from level flight and from a dive. They destroyed vehicles and men from low-altitude flight where guns could be employed most effectively. The IL aircraft unexpectedly appeared over enemy tank and motorized columns, caused panic and confusion and delivered destructive strikes.

Here is what Hero of the Soviet Union N. Platonov wrote about the IL-2's multi-role nature: "There are aircraft which are marvelous creations of human intelligence; their design incorporates everything required for modern combat; they are general-purpose aircraft which can accomplish the most diverse missions; they are aircraft with superior operational performance. The IL-2 belongs to this group of aircraft. This aircraft did a marvelous job of proving itself as a ground attack aircraft. It knew no equal, or even remotely similar, aircraft in any of the armies of the belligerent states. It turned out to be the best battlefield aircraft, both in offensive and defensive operations. In it, pilots achieved the best results in fighting tanks and suppressing all kinds of pinpoint targets and tight targets."

The IL-2 was a complete surprise to the enemy's army; they had no previous knowledge of its existence and, during the war, they were not able to find the equipment or methods to repel its attacks. True, during the first months of the war, while the aircraft was being produced in the single-seat version, the ground attack aircraft suffered losses. At that time, the issue was raised of returning to the two-seat design, which was mentioned above.

In 1942, our group was assigned a difficult and important mission--develop a package of series blueprints within the shortest possible time and with minimal changes to the manufacturing process and plant equipment. A rational solution to the problem was found and, soon afterwards, the front line began receiving aircraft with a defended tail section. The gunner had a rotating gun mount with a large caliber machine gun and he was reliably protected by armor. At the same time that the gunner's compartment was being installed, the power of the AM-38 engine was increased by introducing a power boost regime which made it possible to maintain all the aircraft's flight performance characteristics in spite of the increase in weight.

As a result of this, the IL-2 was an even more formidable weapons system and its range of missions noticeably expanded. With the intoduction of the rear gun mount, it was able to engage enemy fighters on its own; it engaged them at low altitude and usually came out the winner. The IL-2 began to be used to pursue and destroy enemy bombers and, when force groupings were surrounded, to conduct air patrols. Essentially, the ground attack aircraft was a flying tank which was not afraid of being fired upon from the ground or air.

The appearance of the new German heavy tanks, the Tigers and Panthers with their three-inch armor, on the front lines did not take us by surprise. In 1943, the IL-2 was already being produced with two powerful 37-mm cannons. In July 1943, IZVESTIYA wrote in its article "The Tigers are Burning": "Six ground attack aircraft commanded by the courageous Vitruk put 15 tanks out of commission in a single pass over an enemy column."

The effectiveness of the IL-2's bomb load was increased by using hollow-charge bombs. The higher effectiveness of these bombs was due to the increased area effect of the burst; due to this increase, they were able to sharply reduce the weight of the bombs, which, in turn, increased the IL-2's striking power (it was possible to increase the number of bombs on board the ground attack aircraft).

The impact from employing the IL-2 was staggering. With their cannon and machine gun fire, rockets and hundreds of kilograms of bombs, they destroyed enemy men and equipment and sowed fear, panic and confusion. Hitler's army called these formidable aircraft "the black death," from which there was no salvation.

In the Belorussian CP Central Committee Secretary's report to representatives of the Headquarters, Supreme High Command, (7 August 1944), there are the following interesting reports on the IL-2: "The other day, we discovered and inspected a very large, fortified German camp in the woods southeast of Minsk; it had been completely destroyed by our ground attack aviation. This area leaves a striking impression of the scale of destruction and of the demonstrated power of our air force.

"After receiving information on the capture of Minsk, one of the German force groupings built this reinforced area which held over 11,000 men, several hundred tanks, numerous guns and over 5,000 armored vehicles and motor vehicles. This force grouping had large stores of ammunition. The reinforced camp was detected and destroyed by our ground attack aviation. At the time of our inspection, the camp held over 5,000 bodies, more than 5,000 vehicles and a large quantity of ammunition. The entire camp is a picture of the grandiose slaughter of the enemy and his equipment."

In evaluating the role of the "war's great work horse," which the IL-2 was rightly considered to be, PRAVDA wrote in August 1944: "The IL-2 ground attack aircraft is a remarkable forward area weapons system and it has no competitors among the world's fighting aircraft."

While up-dating the IL-2 by increasing its offensive capability and overall combat capability, our group continued to develop this class of aircraft. A new ground attack aircraft was developed in two versions. One of them, the IL-8 had heavier armor and the other, the IL-10, had increased maneuverability. Naturally, the first was somewhat larger in size and had a number of other differences. However, they also had a lot in common, for example: the engines, the wing aerodynamic configuration and load-carrying design, the kinematic design for extending and retracting the gear, etc. The number of offensive and defensive weapons systems on these two versions of the ground attack aircraft were also the same.

The aerodynamic shapes were improved on the IL-8 and IL-10. The AM-42 engine designed by A. A. Mikulin was enclosed in a cowling with a minimal cross-section and the water and oil coolers were transferred from the under-engine section (as on the IL-2) to the wing. The kinematic gear retraction configuration was changed to remove the gear farings. The unsupported (cantilever) struts rotated 90 degrees and were retracted into the well flush with the wing surface.

Consequently, these aircraft did not have any farings which projected out from the aircraft's basic contours. As a result, the IL-10 was half the size of the IL-2 and its speed reached 550 km/hr; this also facilitated a higher thrust-to-weight ratio and the rate of climb was also increased. The IL-10 was also equipped with more modern weapons systems: there were NS-23 cannons in the wings and a UB-20 cannon in the turret.

Both versions were tested. Preference was given to the IL-10 which was put into series production. In October 1944, the IL-10 ground attack aircraft began to enter AF units and they began to participate in the enemy's defeat, especially during the battle for Berlin.

For a while, the course of development for ground attack aircraft continued to be based on piston engines. The IL-16 and the IL-20 were built. The IL-16 ground attack aircraft was designed with the same trends as the IL-10 had. It was further scaled-down in size and its aerodynamics were improved; consequently, its flying performance and maneuverability were also improved. During the design of the IL-20, special attention was devoted to achieving the best view to enhance the accuracy of precision firing against ground-based targets. Because of this, a new general layout was adopted for the aircraft. The rest of this ground attack aircraft was a further development of its prececessors: it had a more powerful engine, better weapons systems, more reliable armor protection, greater speed and range.

When the work on the IL-20 was coming to an end, reliable jet engines had appeared. As a result of this, we found that it was advisable to limit construction to an experimental model and to begin developing the IL-40 jet ground attack aircraft. The latter was a significant qualitative leap forward and it successfully passed the State Tests.

Thus, the ground attack aircraft occupied a special place among Soviet combat aircraft; they played an important role in routing the German forces during the Great Patriotic War.

/Bombers./ Designing and developing various types of bombers was the second trend in the activities of our design bureau. We began by designing the CDB-26 long-range bomber (1933). The first aircraft appeared soon after the MB [medium-range bomber] high-speed bomber had been developed; it had a range of 4,000 km with a bomb load of 1,000 kg. The smooth-skin, all-metal CDB-26 monoplane had a slightly elongated wing with enhanced wing loading, two 760-hp engines and a speed of 403 km/hr. In a subsequent modification with 950-hp engines, its speed reached 430 km/hr. The aircraft crew consisted of three men, just like the MB high-speed bomber.

While the CDB-26 was being designed, both the Experimental Design Bureau and its work style were taking shape. It would be appropriate to point out that establishing a group of single-minded people with an understanding of the science and art of design work, people who were enthusiastic and creative on the job, was just as hard a problem as, for example, developing a good design.

Returning to the CDB-26, it should be mentioned that we designed, built and tested it within a very short period of time. The bombers flying performance and specifications were as good as foreign aircraft of the same type.

A subsequent modification of the aircraft, which was called the LRB-3, was accepted for service with the AF in August 1936 and it went into series production. The testing program for the LRB-3 was accomplished within a short period of time without any delays for touch-ups or additional work; there was no need for them. Its first flight was in March 1936 and, with other aircraft, it participated in the fly-by on 1 May.

With its large load-carrying capacity, the relatively heavy (for those times) LRB-3 had exceptional maneuverability. During the fly-by over Red Square, pilot V. K. Kokkinaki, who was flying the LRB-3, made several standard loops. This made a very strong impression on the people present. The advanced acrobatics, which are characteristic of fighters and training aircraft, were not expected from a large two-engine bomber. While working on further improvements to the LRB-3, the Experimental Design Bureau group put out its next modification to it in 1938; it was called the LRB-3F. At the end of the 30's, more powerful engines were installed in the LRB-3F, its bomb load was increased and its defensive weapons systems and armor plating were reinforced. In 1940, an improved design of the bomber was called the IL-4.

The IL-4 was an all-metal monoplane with two 1,100-hp M-88 air-cooled engines. It had a good aerodynamic shape and fully retractable gear; it had a speed of approximately 420 km/hr, a ceiling of 9,700 m, a range of 3,800 km and a bomb load from 1,000 to 2,500 kg (with a maximum size bomb of 1,000 kg). Its maximum take-off weight was 11,300 kg (with an empty aircraft weight of 5,800 kg) and its wing area was 66.7 m^2. The gross load ratio was 48.5 percent of the aircraft's take-off weight. Consequently, in its basic performance characteristics--speed, load-carrying capacity, range and weight efficiency--the IL-4 surpassed both its family of modifications and all its predecessors.

The CDB-26 bomber and all the subsequent modifications to it--the CDB-30, the LRB-3, the LRB-3F and the IL-4--were distinguished by their superior flying performance. Many world records were set in them at that time. Thus, in 1936, V. K. Kokkinaki broke three world records for altitude with the corresponding controlled weights:

Date	3 August	21 August	7 September
Cargo, tons	0.5	1.0	2.0
Altitude, m	13,178	12,101	11,005

Then, in August 1937, V. K. Kokkinaki and A. M. Bredinskiy set a new world record: an aircraft with a load of 1,000 kg sustained an average speed of 325 km/hr on a 5,018 km route: Moscow--Sevastopol'--Sverdlovsk--Moscow. On 27 June 1938, the IL-4 Moscow made a non-stop flight along a 7,600 km route from Moscow--vicinity of Vladivostok (Spassk) in 24 hr 36 min at an average speed of 307 km/hr. This flight was conducted under adverse weather conditions. On 28 April 1939, an IL-4 flew non-stop from Moscow via Greenland across the Atlantic Ocean to North America (St Lawrence Island) along an 8,000-km route in 22 hr 56 min at an average speed of 349 km/hr.

During the years that Soviet military aviation was being developed, the major achievements and world records set in our aircraft, as well as in those designed by A. N. Tupolev, P. O. Sukhoy, N. N. Polikarpov and V. M. Petlyakov, received a broad response within our country and abroad.

But, our aircraft were not built for the sake of setting records. The bombers reviewed above were truly military aircraft. Having appeared before the war, they were not only at the state of the art but they were able to incorporate the immediate future state of the art in aviation. Thus, the IL-4 remained in service throughout the Great Patriotic War and was used as a multi-role aircraft.

It was the primary long-range bomber. Our pilots made the first night flights to Berlin in this aircraft and, later, continued making them for a long time. In addition, the IL-4 was successfully employed as a tactical bomber to destroy concentrations of enemy men and equipment on the front lines and in the immediate rear area. It was also used as a torpedo bomber.

This bomber was in series production. Altogether, 6,890 IL-4's were built.

The design of this aircraft was a great deal different from that of its predecessors. We rejected the corrugated sheet and tubular spars--the primary load-bearing wing structure--and went over to extruded sections. For the first time, the fuel was located directly in the wing without any tanks. True, this solution could only be partially implemented on a military aircraft since the primary fuel reserves were still located in reliably protected tanks. This idea was subsequently developed both abroad and at home--in the IL-18 and IL-62.

The IL-4 had a gun weapons system to defend against enemy fighter attacks. This made it possible for it to carry out combat sorties at night without fighter escort and with fighter escort during the day. The weapons system consisted of two rotating and one fixed gun mount. The turret for defense of the upper hemisphere had a large caliber machine gun. Shpital'nyy-Komarnitskiy rapid-fire machine guns were installed in the fixed forward and rotating bomb bay weapons stations.

The crew was reliably protected by armor. The bottom and back of the pilot's seat were made from thick steel armor. The IL-4 had a powerful liaison radio set, a fixed-loop radio compass, an autopilot and other equipment required for long-range flights.

The 360 degree gun and effective armor protection systems and the high structural reliability made the aircraft invulnerable.

The IL-4's reliability, which was also designed in, was supplemented by the ability to continue a long-range sortie with a single engine in the event the other failed or took a hit. Pilot F. Parashchenko's case can serve as an example of this. While carrying out a routine mission deep in the enemy's rear, one of his engines was put out of commission by an enemy shell. An extremely difficult situation developed; it was necessary to get out of the range of anti-aircraft artillery and to cover an enormous distance with one engine. In spite of the difficulty, the aircraft returned to its home base. The title Hero of the Soviet Union was awarded to the courageous pilot F. Parashchenko, who had 350 combat sorties in the IL-4 bomber.

It is well known that the merits of an aircraft are only discovered when it is compared to other models, usually foreign ones. For an objective evaluation, it is advisable to select aircraft of the same type and of approximately the same design year. Guided by this, the basic data are shown in Table 1.

Table 1. Basic Bomber Data

(1) Самолет	(2) Год выпуска	(3) Мощность двигателей	(4) Полетный вес, кГ		(5) Максимальная скорость, км/ч	(6) Высота, м	(7) Время набора высоты, мин.	(8) Потолок, м	(9) Вес бомб, кГ, норм./макс.	(10) Дальность, км, норм./макс.
			(a) норм.	(b) макс.						
Ил-4	1938	2×1100	8 380	11 300	429	6700	12,0	9700	1000/2500	2600/3800
HE-111H	1939	2×1175	11 300	12 400	418	4000	16,8	7300	1000/2000	2400/—
(11) «Веллингтон»	1939	2×1050	11 700	11 700	378	—	—	5800	2050/—	2900/4100

Key:

1. Aircraft
2. Production year
3. Engine power
4. Weight, kg
   a) normal
   b) maximum
5. Maximum speed, km/hr
6. Altitude, m
7. Time to climb
8. Ceiling, m
9. Bomb load, kg, $\frac{\text{normal}}{\text{maximum}}$
10. Range, km, $\frac{\text{normal}}{\text{maximum}}$
11. Wellington

It follows from the table that the IL-4 bomber surpassed similar bombers in flying performance and specifications, both our Ally's bomber, the British Wellington--and the enemy's bomber--the German Heinkel HE-111H.

As noted, the IL-4 was a modification of the LRB-3 and it was adopted for service five years before the war began. Consequently, our group was able to correctly get its bearings on the problems of preparing for the war and of modifying an aircraft while keeping it at the state of the art for foreign aircraft at that time.

Soon after the treacherous fascist attack on our country, on the night of 8 August 1941, a formation of IL-4 long-range bombers carried out a raid on military targets in Berlin. This came as a complete surprise to the fascist invaders. The city was brightly lit that night. From that time forward, the black-out was not raised in Berlin until the end of the war. Our IL-4's delivered concentrated strikes not only against Berlin but also against other military targets in the enemy's heartland.

The IL-4's not only bombed enemy military-industrial targets, they also aggressively participated in the battles at the front lines of the Great Patriotic War along with the other branch arms. Here is what Hero of the Soviet Union AF ColGen S. Ushakov wrote in this respect: "In the fall and winter of 1941, exceptionally stubborn battles were unfolding in the Moscow sector. Long-range bomber aviation took an active part in these battles along with the other branch arms. During the battle at Moscow, night time lone-wolf operations in IL-4 bombers proved themselves as an effective form of combat operations. The lone-wolf crews delivered strikes against trains on open lines, blocked major rail lines and also interdicted the enemy's night time airfields which were used for raids against Moscow." Our pilots frequently followed the fascists who were returning from a mission and, when they turned the landing lights on, they delivered accurate strikes against aircraft hardstands.

After their major defeat at the Volga, Hitler's command began to mass large air force groups--up to 1,000 aircraft--in the Crimea for new operations in the Caucasus and southern Ukraine. Two bomber corps, primarily made up of IL-4's, delivered continual strikes against enemy airfields. During a period of several days in April, 70 aircraft were destroyed at Sarabuzskiy Airfield, 100 were destroyed at Sakskiy airfield and numerous EM and officers, including 36 pilots, were killed. The same thing happened at other airfields.

The combat operations in the Baltic Sea, the Polar Region, the Barents Sea and the Black Sea Theater occupy a special place among the glorious deeds of Soviet pilots. IL-4's which were specially equipped to carry torpedos, pursued and sank Hitler's transports, destroyers, escorts and landing barges. Our aircraft escorted allied convoys by preventing and disrupting fascist submarine attacks; they delivered appreciable strikes against naval bases.

In spite of the fact that the primary efforts of our group were directed at developing ground attack aviation during the war, we continued to work on the development of a more up-to-date bomber. In 1943, the IL-6 was built; it had the ACH-30V economical 20-cylinder engines designed by A. D. Charomskiy; these engines worked on heavy-duty fuel.

The IL-6 bomber had the same aerodynamic shape as the IL-4 but it was larger in size. The crew size was increased to six and the defensive weapons system consisted of five 20-mm Shpital'nyy-Volkov wing-mounted aircraft cannons. Moreover, the aircraft had rotating airborne mounts. This new aircraft's speed was 464 km/hr with a range of 4,000 km and a ceiling of 7,000 m.

Unfortunately, the diesel engines mentioned above were not improved and this kept the aircraft from going into series production; it was not possible to reequip the aircraft with different engines. Its size was precisely matched to the power of these engines.

Beginning in 1944, the Experimental Design Bureau group worked on the development of turbo-jet aircraft. In 1946, the IL-22 jet prototype with four TR-1 engines designed by A. M. Lyul'ka was built and underwent flight testing at the plant.

It, like similar aircraft of other design organizations, was used to study many problems of jet aviation; the solution to these problems was required to develop new equipment in our country. Besides these principal problems, many new design solutions were tested and new domestic jet engines were also tested and developed.

The results of the tests with the IL-22 and the experience obtained from designing it made it possible for the design bureau group to develop the first jet tactical bomber (of those accepted for service) in our country within a short period of time; it was the IL-28 with the VK-1 engines designed by V. Ya. Klimov. After successfully passing the State Tests, this aircraft was put into series production and introduced into the AF inventory.

Before beginning to design the IL-28, or rather, before the initial design tasks--selecting the aircraft configuration and size--it was necessary to solve the problem of its defensive armament. The number of crew members, the aircraft weight, the engine thrust, the configuration, the wing size, the fuselage, etc., were dependent upon this.

At that time, there was no uniform approach to a solution of this problem in the world experience in aircraft production. Thus, taking into account the irrefutable success of the Mosquito they had built during the war, the British aircraft designers decided to continue developing a medium-range bomber force with the same tactical concept. The Mosquito did not have turret-mounted guns to defend the rear hemisphere; the fixed, forward-firing cannon did not make it possible to engage enemy fighters which it surpassed in speed. Thus, their refusal to defend the rear of the aircraft was based on this small bomber's superiority in speed; in size, there were only insignificant differences between a fighter and this aircraft. As a result, the British simply armed their first jet bomber with a fixed, forward-firing mount.

We believed it was questionable to design a bomber which was not defended against attacks from the rear and we also believed it was questionable to rely on its superiority in speed. The fact was that aircraft engineering was developing primarily on an even keel in different countries, or rather, with small variations in the state of the art over time. Superiority in some areas did not last long and would soon be cancelled by superiority in other areas. As far as the British reliance on superiority in speed while developing the Mosquito was concerned, it was justified at that time since even a temporary superiority (over a 2-3 year period) had an impact during the war.

Later on, especially with the appearance of radar sights, it became risky to adhere to the British wartime concept. These sights could detect a target many kilometers away and they could support accurate gunfire against an enemy beyond visual range.

In spite of the aircraft's high speed, we were convinced of the need to defend the rear hemisphere; so, we designed a rear turret mount (called the IL-K6) into the IL-28; it had two hydraulic-powered 23-mm cannons. The gunner's compartment, which was also located in the aft part of the fuselage, was reliably protected by transparent metal armor. The gunner's seat could be ejected downward during emergencies. The other crew members--the pilot and navigator--

also had these kind of seats, only with upward ejection, and reliable armor protection.

Two fixed gun mounts with NR-23 23-mm cannons were located in the forward section of the fuselage. The bomb load was 3,000 kg.

The IL-28's navigational and electronic support equipment supported flight operations and ground-based target acquisition and destruction at any time of the day and also under adverse weather conditions.

During the development of the IL-28 and other jet aircraft, it was possible to obtain a good combination of flying performance and handling performance. With its high speed, the IL-28 was easy to control and was distinguished by its stability and maneuverability. The aerodynamic configuration, shape and control elements were developed in close cooperation with the CAHI which provided a great deal of assistance in solving these problems during the design phase of all aircraft.

The IL-28 developed a speed of 900 km/hr with a range of 2,400 km at an altitude of 10,000 m. Its ceiling was 12,300 m. The load ratio was 40 percent of the take-off weight which was 21,200 kg. Thus, the speed and operational altitude of the IL-28 exceeded the speed and operational altitude of tactical bombers during the war by a factor of 2 with a significantly larger weight due to the bomb load, weapons systems and various equipment systems. This is why the initial attempts to develop jet aircraft using piston-engine airframes was not promising.

The IL-28 was designed and built in several modifications for use in various roles. Thus, the IL-28R reconnaissance aircraft and the IL-28U training version were put into series production. Later, the IL-28T torpedo bomber was built on the basis of the IL-28.

Our experience in developing this aircraft, as well as other combat aircraft, confirms our accepted proposition that the designer must always be both a tactician and a production engineer. Actually, only a knowledge of the combat employment features of the airframe being designed will lead to the development of aircraft which are most appropriate for their role; this has been proven by experience on numerous occasions. Only such aircraft can make it big in aviation.

In turn, a comprehensive analysis of tactics made it possible to incorporate the tactics of cooperation between air and land forces--which were predicted for World War II which was approaching at that time--in the overall configuration of the IL-2 as well as in its weapons systems and armor configuration. There is no doubt that the appearance of new equipment brings about the requirement to develop new tactics. In our case, it was the tactics of ground attack aviation.

In this respect, PRAVDA wrote: "Il'yushin's aircraft is not simply an achievement in aviation science. It is also a remarkable tactical discovery. It is based on a profound, accurate idea...."

This is how it was with the IL-2 ground attack aircraft; the IL-4 bomber was a repeat of this. An analysis of the tactics made it possible for us to get our bearings correctly in preparing for the war. This had a definite effect on the fate of the IL-22.

Incidentally, the IL-28 bomber's fate was similar to the IL-2 and several of our other aircraft: certain customer representatives took a cold and even negative attitude toward the idea of developing these aircraft; in the final analysis, they entered mass production.

During those years, there was a widespread practice (which is described in detail in A. S. Yakovlev's book "The Purpose of Life") of giving the same assignment to 2-3 design organizations. Work was conducted on the aircraft almost concurrently and a spirit of competition reigned all the time in the groups. In connection with this, I remember a meeting with I. V. Stalin where the results of the State Tests for two proposed aircraft were reviewed. Stalin thoroughly reviewed the data submitted, listened to the opinions of the military and decided to put the IL-28 bomber into service.

I won't hide the fact that this decision made us happy; but we understood that it gave us a lot of obligations. The deadline for expanding series production was extremely tight: by the May holidays, it was necessary to build the five aircraft which would participate in the fly-by. Our entire Experimental Design Bureau was mobilized to accomplish this assignment. The series plant did a lot of good work. The assignment was accomplished by the deadline and the aircraft participated in the fly-by.

A complete comparison (of the types shown in the table) between similar bombers--the RAF Canberra and the USAF Martin B-57 Canberra--cannot be made unfortunately; it is not possible due to a lack of published, systematic data. In addition, the IL-4, the Heinkel HE-111H and the Wellington were not only the same type aircraft in role and size but also in relation to their defensive weapons systems--they all had a defense for the forward and rear hemispheres. The same cannot be said when comparing the IL-28 and the Canberra. True, one of the last modifications to the Canberra--the Mk-8--had a fixed gun system but it was only forward-firing.

The speed of this aircraft was 871 km/hr (the IL-28's speed was 900 km/hr); the maximum bomb load was 2,410 kg (versus 3,000 for the IL-28); the aircraft's operating weight was 12,680 kg while the operating weight for the IL-28 bomber was somewhat larger due to the rear turret; it was 12,890 kg. Without the turret, it would have been lighter since the installation of the turret and its related complication of the tail section configuration and the installation of the gunner's compartment with its rather heavy transparent metal led to an increase in the empty weight of more than 1,100 kg, not counting the increase in the weight of the rear part of the fuselage which was loaded down with the rear cannon mount.

The British Canberra was designed for long-range flights. Because of this, engines with enhanced thrust were selected for it. For this reason, the take-off weight of the British bomber was somewhat higher. Although this is an incomplete comparison, it is nevertheless possible to conclude that the IL-28 surpassed its foreign peers in combat effectiveness.

In developing this line of bomber aircraft in subsequent years, our group built the IL-46 and IL-54 bombers; they had a greater operational radius and, naturally, larger tonnage and load-carrying capacity.

The IL-46 was a tactical bomber with a range of approximately 5,000 km and a maximum bomb load of 6,000 kg. The aircraft was planned in two versions: one with a straight wing and the other with a swept wing. In the first version, it developed a speed of 930 km/hr and its ceiling was 12,300 m. It did not differ from the IL-28 in layout, configuration and defensive weapons systems.

The next bomber with the same role, the IL-54, had two engines designed by A. M Lyul'ka. In contrast to the IL-46, it differed from its precedessors in both its layout and configuration. While the two previous jet bombers were mid-wing monoplanes, the new one was built as a high-wing monoplane. The IL-54's wing had a large sweep angle--55 degrees--and it had bicycle gear. The engine nacelles were mounted on pylons. At that time, the fuselage design presented a difficult problem. The problem was that the airframe was cut almost along the entire length of the bottom by the two landing gear bays and the bomb bay which made it possible to load large bombs and torpedos.

Like the others, these aircraft were built at the minimum size and tonnage to accomplish the given flying performance. The aircraft successfully passed the plant and State Tests where the performance obtained corresponded to the designed performance.

/Piston engine and turbo-prop airliners./ It is necessary to immediately point out that it is by no means easier, and perhaps more difficult, to develop a modern airliner which is recognized by the passage of time, than it is to develop aircraft with other roles. This will become clear if you recall that, in many respects, increased requirements are levied on passenger aircraft and the number of these requirements are increasing all the time. The designer has to think about flight safety and operational economy and about how to obtain maximum cruising speed with the least expenditure of fuel. Moreover, the following requirements also should not be forgotten: long service life and reliability, all weather capability and regularity, passenger comfort and crew conveniences. Finally, it is necessary to achieve a minimum level of noise in the cabin and near the airport and to ensure high service life and enhanced repairability for the aircraft. In addition, subsequent generations of aircraft should invariably surpass their predecessors in basic requirements and they should have developmental potential. These tasks are also not easy. It can be stated without exaggeration that the only aircraft which will make it big in aviation is the one which satisfies the listed requirements the best.

While efficiency in combat aircraft is achieved by designing them on the basis of scientific achievements and by forecasting the tactics for air engagements, efficiency in airliners is achieved by a scientific and economic approach to all the design processes and also by studying the trends in transport development.

The design system which was developed in our Experimental Design Bureau and which has been used on a practical basis for a period of 35 years takes the above into account. It facilitates the development of reliable and efficient aircraft,which are easy to handle and which have a light and technologically effective airframe. This system also ensures the unconditional accomplishment of all the flight performance characteristics and other characteristics set forth by the designs.

The idea of developing an airliner arose during the Great Patriotic War. In 1943, while the military IL aircraft were carrying out their combat missions, our Experimental Design Bureau began to design new equipment for the civil fleet. It was necessary to develop an aircraft with a flight performance which would surpass the state of the art abroad.

While developing the IL-12--the first of the IL airliners--we tried to lay the foundation for a new trend in the development of domestic aviation, a trend which was characterized by a desire for a high degree of economy and maximum weight efficiency and by searching for a new style to outfit passenger cabins (this style, incidentally, was subsequently called "the style of pleasant simplicity").

While designing the IL-12, we paid special attention to reliability and safety. These requirements ran like a red thread through all the planning, design, testing and systems development processes.

Our concept of the safety problem took shape along with our design work on the IL-12. We understood that a high degree of safety could be achieved both through design solutions and through planning solutions. It could be achieved by selecting the number of engines and the appropriate values for the power-to-weight ratio and the aircraft's aerodynamic configuration and by developing control elements and an airframe with enhanced survivability and reliability for all the power plant and equipment systems. For example, fire safety could not only be ensured with fire extinguishers, it could be designed into the power plant configuration, the fuel system and various equipment systems.

Another airliner problem which we also always considered as a primary one was developing systems which were distinguished by their handling and operational ease and simplicity. Smooth and well tuned control systems improved crew working conditions and, in the final analysis, they enhanced flight safety.

Like flight safety, a high level of economic efficiency for the aircraft depends upon the solution to a large package of various problems which appear during all phases of aircraft development--from the preliminary design to the working design. Problems of economy should always be within the designer's scope. And, finally, there is the weight problem. It is also closely related to economy. Naturally, only an aircraft which is distinguished by safety and a light airframe can be a high-volume transport.

How can weight efficiency be guaranteed for an airliner? First, by selecting a rational size, with a high density layout for all types of cargo and equipment systems and, then, by solving all the design problems with a strict limit on minimum weight.

The IL-12 had two ASH-82FN piston engines designed by A. D. Shvetsov, each with a take-off power of 1,850 hp. It was put into series production in 1946 and was built before the IL-14 went into operational use. Both of these aircraft (data on them is shown in Table 2) were all-metal monoplanes with low-set, tapered wings. In contrast to their predecessors, they had tricycle landing gear which could be completely retracted into the engine nacelles and the fuselage. Their baggage compartments were located under the cabin floor and were designed to hold baggage, mail and cargo. The cabin was equipped with a galley.

One of the most difficult problems in designing a twin-engine aircraft is finding a compromise between weight and economy performance, on the one hand, and ensuring a safe take-off when one of the engines fails, on the other hand. During the preliminary design phase for the IL-12, an optimal solution was found for it. Sufficiently good weight performance was obtained and flight safety was ensured. The reserve power made it possible for the aircraft to climb on one engine to 2,500-3,000 m. Obviously, this aircraft could continue level flight if one of its engines failed on a trip. The take-off run was 460 m; therefore, the IL-12 was based at small airfields.

The IL-12 was built in several versions, including a cargo version and assault transport version. The former was designed to carry 3,500 kg of diverse cargo while the latter was designed for assault landings and para-drops of men, light equipment and cargo.

The IL-14 was a subsequent development in airliners; it entered Aeroflot's short-range and medium-range routes in 1954.

More powerful engines and more modern equipment were installed on it. In layout, it was the same as the IL-12; however, the architectural shape and aerodynamic configuration of the wing and tail section were different and the fuselage was longer. The number of passenger seats was increased.

The IL-12 and the IL-14 were in series production for ten years. The IL-14 also had a large number of versions (an airliner with cabin configurations for various numbers of seats, an assault transport and cargo aircraft and, finally, a VIP version to transport various delegations).

Their large-scale, long-term operational use in the Soviet Union and other countries and their widespread employment by scientific expeditions to the North and South Poles, i.e., operational use in the most diverse geographical environments, have demonstrated the superior flying performance and economy of the IL-12 and the IL-14. The IL-14 demonstrated this performance and operational safety specifically during the visits of governmental delegations to India, Burma and Afganistan in 1955 by flying 22,500 km.

Nevertheless, the pros and cons of airliners, as with other types of equipment, are seen when compared to foreign models. With this in mind, we can continue our previous course of comparing aircraft in the same class and of approximately the same size in the table shown below. They make it possible to judge the state of the art for airliners. In this case, let's compare the basic specifications for the IL-12 and IL-14 airliners with the corresponding foreign models--the American DC-3 and the British Viking (see Table 2). Notice that it is more difficult to compare aircraft operational merits which are not related to their basic characteristics. The difficulty properly consists of selecting objective criteria for a comprehensive evaluation. For an example, we can cite one of the designed-in aircraft statistics for repairability, namely, the number of hours required to change engines. At one time, this was a large figure. Now, for aircraft with turbine engines, it is within the range of 2-3 hours for a single-engine prepared in advance. This figure for IL aircraft is as good as the one for foreign aircraft.

Table 2

(1) *Характеристика*	*Ил-12*	*Ил-14*	*DC-3*	(2) *«Викинг»*
(3) Взлетный вес, *кГ*	17 250	17 500—18 000	11 400	15 400
(4) Вес пустого самолета, *кГ*	11 000	12 500	7660	10 900
(5) Число пассажиров	27—32	36—40	21	36
(6) Максимальный вес коммерческой нагрузки, *кГ*	2620—3160	2970—3550	1970	3200
(7) Дальность при максимальной нагрузке (техническая), *км*	2200	1100—1400	1060	1850
(8) Максимальная дальность полета (техническая), *км*	3300	2150—2550	2680	3600
(9) Крейсерская скорость, *км/ч*	320	350	274	336
(10) Максимальная скорость, *км/ч*	407	430	—	—
(11) Весовая отдача, %	36,2	29,0	23,0	29,0

Key:
1. Characteristic
2. Viking
3. Take-off weight, kg
4. Empty weight, kg
5. Passengers
6. Maximum payload, kg
7. Range with maximum payload (dry tank), km
8. Maximum range (dry tank), km
9. Cruising speed, km/hr
10. Maximum speed, km/hr
11. Load ratio , %

In Table 2 it is easy to see a rather strict match between take-off weight and empty weight, between number of passengers and empty weight and between the size of the payload and the range to which it is being transported. Thus, the Viking was designed for a somewhat larger number of passenger seats but for a smaller range than the IL-12; the DC-3 was built with smaller values for its basic dimensions and a correspondingly lower take-off weight. At the same time, the engineering efficiency of all these aircraft is approximately at the same state of the art.

In 1947, we designed and built an aircraft which is significantly larger than the IL-14, the IL-18, with four ASH-73 piston engines designed by A. D. Shvetsov and a take-off weight of 42,000 kg. The passenger cabin was designed for

60 passengers with first-class seating (tourist and economy-class seating appeared later). This aircraft's non-stop range was 6,200 km at a cruising speed of 500 km/hr; its maximum speed was 588 km/hr. The aircraft testing confirmed all the data in the preliminary design.

Ten years later, in 1957, we built another airliner with the same IL-18 designation; but, its specifications and economic performance had nothing in common with the aircraft discussed above. There was only a match in certain geometrical parameters (for example, wing area and fuselage diameter). Naturally, we used the design experience from the large airliners at that time.

The new IL-18--with its four AI-20 turbo-prop engines designed by A. G. Ivchenko, each with an equivalent thrust of 4,000 hp--made its first flight on 4 July, 1957. It was primarily distinguished from its piston-engine "colleague" by its take-off weight, which was 1 1/2 times greater and, consequently, by its payload. The speed was increased by more than 30 percent and the cruising altitude was increased to 8,000-9,000 m.

This engineering leap forward was possible due to the appearance of turbo-prop engines. They were the ones that laid the foundation for the development of turbine passenger aviation.

The IL-18 has a pressurized fuselage equipped with a conditioning system that makes it possible to create normal passenger living conditions while flying at high altitude. The development of large fuselages with a high degree of pressurization and a large number of cut-outs for windows, hatches and doors was a difficult problem at that time. It was necessary to solve a large number of difficult design problems. Let's list a few of them. First of all, it was necessary to develop an airframe which was not subject to catastrophic failure due to material fatigue, or, in other words, it was necessary to guarantee the aircraft's fatigue strength and long service life. Moreover, survivability had to be achieved with a minimal increase in weight. Our group was able to solve these problems. We developed an aircraft with a viable and, at the same time, light airframe.

The IL-18 was designed to carry a 14 ton payload. The IL-18's maximum speed was 730-750 km/hr while its economical cruising speed was 650 km/hr (Table 3). With an auxiliary power plant, the payload was 13,500 kg. The number of passenger seats in this aircraft can vary within a broad range depending on the type and class of the cabin configuration. The maximum number of seats has changed as different modifications to the IL-18 have appeared (Table 4).

Table 3

(1) Характеристика	(2) Ил-18В	(3) «Вэнгард-953»	(4) С увеличенным взлетным весом	
			(a) Ил-18Д	(b) «Вэнгард-952»
(5) Мощность двигателей, л.с.	4×4000	4×4850	4×4250	4×5325
(6) Взлетный вес, кГ	61 200	64 000	64 000	66 450
(7) Вес пустого снаряженного, кГ	34 500	37 880	35 300	38 785
(8) Максимальный вес самолета без топлива, кГ	48 000	51 030	48 800	55 565
(9) Число пассажиров	89—100	139	100—110	139
(10) Максимальный вес коммерческой нагрузки, кГ	13 500	31 150	13 500	16 780
(11) Дальность практическая при максимальной нагрузке, км	2700	2780	3700	3300
(12) Максимальная техническая дальность, км	5400	—	7100	4840
(13) Коммерческая нагрузка при максимальной дальности, кГ	8600	—	6500	10 500
(14) Крейсерская скорость, км/ч	650	660	650	676
(15) Площадь крыла, $м^2$	140	142	140	142
(16) Удельная нагрузка на крыло, $кГ/м^2$	437	450	457	465
(17) Весовая отдача, %	43,5	40,8	44,8	41,5
(18) Производительная отдача, $Т \cdot км/кГ$	0,6	0,57	0,8	0,83

Key:
1. Characteristic
2. Il-18V
3. Vanguard-953
4. Increased take-off weight
   a) IL-18D
   b) Vanguard-952
5. Engine power, h.p.
6. Take-off weight, kg
7. Empty weight, kg
8. Maximum unfueled weight, kg
9. Passengers
10. Maximum payload, kg
11. Operating range with maximum payload, km
12. Maximum dry tank range, km
13. Payload for maximum range, kg
14. Cruising speed, km/hr
15. Wing area, m^2
16. Maximum wing loading, kg/m^2
17. Load ratio, %
18. Productivity ratio, $T \cdot km/kg$

Table 4

(1) Характеристика	(2) Ил-18А	(3) Ил-18Б	(4) Ил-18В	(5) Ил-18Д	(6) Ил-18Е
(7) Взлетный вес, кГ	59 200	61 200	61 200	64 000	64 000
(8) Число пассажиров	75	84	89	100—110	122
(9) Дальность полета (техническая) с максимальной коммерческой нагрузкой, км	3300	3300	3300	4300	3300
(10) Максимальная дальность полета (техническая), км	5400	5400	5400	7100	5400

Key:
1. Characteristic
2. IL-18A
3. IL-18B
4. IL-18V
5. IL-18D
6. IL-18E
7. Take-off weight, kg
8. Passengers
9. Range (dry tank), with maximum payload, km
10. Maximum range (dry tank), km

A detailed, comparative analysis is presented in Table 3 for an objective evaluation of the IL-18. For this purpose, we selected a smaller aircraft in power plant and size--the medium-hull British turbo-prop Vickers-Vanguard which was designed almost concurrently with the IL-18. Moreover, one of the first and last modifications are compared.

As indicated, the IL-18D has an increased range compared to the IL-18V; with an increase in take-off weight, the Vanguard's payload increased. Previously, it was 13,150 kg and was somewhat less than the IL-18 had; but, in the later modification, it was 16,780 kg but was transported to a smaller range than was the IL-18D's payload. The same relationship also holds for maximum range.

The load and productivity ratio criteria (see Table 3) show a significant increase in the efficiency of subsequent modifications and in the state of the art for the aircraft being compared. The first of these objective criteria is the ratio of payload to maximum take-off weight and it is expressed as a percentage; the second is the ratio of productivity for the trip in ton-kilometers (the product of payload weight times range) to maximum take-off weight.

The IL-18 was in production for ten years. Consequently, its complete operational life is at least 20 years. The aircraft's extended life was not only guaranteed by the high degree of reliability and economy designed into the configuration and airframe but also by its promise for the future which consisted of periodically increasing the number of passenger seats and the range. This is graphically illustrated by the data in Table 3.

In addition to the modifications cited in this table, the IL-18 was produced in a VIP version with large specially equipped passenger compartments.

A number of world records have been set in the IL-18.

The IL-18 was built in large numbers and is presently accomplishing a significant part of Aeroflot's passenger services. It is also the primary means of air transportation for the socialist countries. The American magazine Life noted that the IL-18 is "the workhorse of the Eastern European airports."

A large number of IL-18's are exported to foreign countries and these aircraft fly on many of Aeroflot's international routes. Evidently, there is not a single country in the world where the IL-18's have not visited. They also fly to the North and South Poles. In their IL-18 and AN-10 air ships, polar pilots have made two flights to the Antarctic which were exceptional in their length and complexity.

/Turbo-jet airliners./ The first turbo-jet airliner built by our group was the IL-62 multi-seat, intercontinental airliner. Its flight testing began in 1962. Four turbo-fan engines designed by N. D. Kuznetsov, each with a thrust of 10,500 kg, are installed on the rear of the fuselage in this aircraft. As is well known, this engine configuration makes it possible to build an aircraft with a higher degree of safety, enhanced passenger comfort and higher aerodynamic wing efficiency than aircraft with a wing-mounted engine configuration have. However, this design raises a number of complex problems for designers and only an optimal solution for them will lead to the development of an economical and dependable aircraft.

While developing the modern IL-62 airship, we attempted to design into it the best engineering and scientific achievements of the domestic and world aviation, electronics and other industrial sectors. We devoted just as much attention to guaranteeing a high degree of safety, which primarily consists of the fact that the aircraft, with its four engines and the corresponding power-to-weight ratio, can continue its take off when one of the engines fails and it can continue cruising when two engines fail. It can make a second circuit on approach with two engines feathered.

Along with the characteristics establishing this level of flight safety, we were able to combine rather high flying performance and engineering specifications in the wing and aircraft configurations. This was achieved by a special aerodynamic wing configuration and by a thoroughly developed interface between the tail section and the engine nacelles, and also by a number of design solutions which established, for example, the use of manual override controls on the aircraft.

The estimates and aerodynamic studies on aircraft models made it possible to find a rational shape for the wing in terms of having an optimal combination of aerodynamic, strength and weight parameters.

Special attention was devoted to aircraft performance at large (critical and supercritical) angles of attack which have an effect on flight safety under turbulent atmospheric conditions. The problem was one of obtaining a flow over the wing surface which, while not degrading aircraft performance in cruising regimes, would guarantee pitch stability within a wide angle of attack envelope. A contour with a special distribution law for the span of the wing section camber and geometrical warp of the section was developed; the locations of the horizontal tail section and the engine nacelles were carefully selected.

The flight control and navigational equipment, electronic support and radar equipment systems support the IL-62's automated flight throughout its track, beginning at an altitude 200 m (after take-off) and ending at the approach altitude. Because of this, the aircraft can fly under adverse weather conditions, at all latitudes and at any time of the day or year; this enhances its regularity.

When necessary, the automatic flight control system makes it possible to maintain a designated speed during climb and descent, a designated flight level and a designated (programmed) flight route in the horizontal plane based on inputs from the navigation computer.

Flight safety is guaranteed by numerous back-up systems and by the presence of a system to monitor a number of parameters. The automation of the most important part of the flight--the approach--makes it possible to reduce the aircraft's weather minimums in addition to enhancing flight safety.

The IL-62 has manual and not powered control: it is reliable and structurally simple; it requires minimal service and reduces aircraft costs. The development of this control system for a large aircraft required a significant amount of aerodynamic, research and design work on the methods for acting on the hinge moments for control elements.

Another difficult problem in designing a jet airliner--which was also successfully solved during the IL-62's development--was reducing internal and external cabin noise. The foreign press is presently discussing more rigid standards for aircraft noise in local areas. The magazine AVIATION WEEK AND SPACE TECHNOLOGY (25 March 1968) pointed out: "At present, only a few three-and-four-engine jet aircraft stack up under the proposed noise standards. They include: the American Lockheed C-141, the Soviet's Il'yushin IL-62 and the British BAC VC-10." In the article 'Challenge to the West,' which was published in the American magazine LIFE (26 July 1968) and which was devoted to the IL-62's first trips on its Moscow-New York run, the author wrote: "The IL-62 is a good aircraft. The passengers on the New York trip found that the seats are wider and more comfortable than on Western turbo-jets and the four aft-mounted engines make the trip more peaceful and quiet." The author further notes that "Aeorflot business circles have very serious intentions to make a profit: they have already contracted to sell their new IL-62's, which are their pride and joy."

As far as passenger comfort is concerned--which is very important in air transportation--the American newspaper EVENING STAR pointed out, when the IL-62 appeared in the U.S., that "both cabins are tastefully and simply decorated.... The interior decoration in the IL-62 is of surprisingly high quality. The cabin conveniences, from major ones to trifling ones, are as good as the Western standards of comfort."

From the relatively light, 17-18 ton IL-12 and IL-14, we transitioned to the 42-ton IL-18 (with piston engines) at first and then to the 64-ton IL-18 (with turbo-prop engines) and, finally, we built the IL-62 with its take-off weight of

160 tons. To a certain extent, this made it possible for us to observe continuity in many design solutions.

When we talk about types of power plants, our Experimental Design Bureau first developed piston engine airliners and then arrived at the heavy turbo-jet aircraft after first designing and building a medium-weight turbo-prop aircraft. Estimates led us to conclude that aircraft in this class with turbo-fan engines would be more economical for a certain period of time. And, actually, the turbo-jet aircraft began to compete with the turbo-props somewhat later when the turbo-fan engine appeared with its low fuel consumption and relatively light weight.

When the IL-62 made its appearance, it differed from domestic jet aircraft in external appearance by its aft-mounted engines. This configuration for an airliner was first implemented on the French Caravelle. Opinions on this design were mixed at first within our aviation cirles but, then other aircraft like this appeared. Actually, the fuselage engine configuration is rather controversial. With all its merits, it has its deficiencies, primarily, the weight loss. New solutions had to be sought to minimize these costs. The research conducted by our Experimental Design Bureau demonstrated the feasibility of locating the power plant on the fuselage for a four-engine, heavy airliner design with a new configuration for take-off and landing devices.

A lot of new and no less controversial things have also arisen in other areas of aviation development. It is clear that new equipment cannot be developed without studying the laws of its development. It is necessary to carefully follow everything new in science and practical experience and use it after considering the specific operational environment.

In looking at modern airliners, it is possible to see that many firms' aircraft have a lot in common in external appearance. However, this common architectural resemblance hides significant differences.

Design problems which are solved in different ways include, for example, one of the cardinal issues--stability and controllability.

Our Experimental Design Bureau group did a lot of productive work studying the issues of aircraft stability and controllability. Thus, the relative area of the horizontal tail section on the IL-18 and IL-62 is almost 1 1/2 times smaller than that for similar British aircraft. At the same time, the stability and controllability of our aircraft meet international standards. The value for the super-critical angle of attack for the IL-62 is as good as the one for similar foreign aircraft.

As far as weight efficiency is concerned--which has an exceptional effect on aircraft economy and which results from the solution to numerous planning and design problems--the IL-18 and IL-62 are also as good as foreign aircraft. The data shown in Table 5 confirm this.

Table 5

(1) Характеристика	(2) Ил-62	(3) «Супер» VC-10	DC-8-40	(4) «Боинг-707»
(5) Весовая отдача, %	57,0	53,0	58,0	57,5
(6) Относительный вес планера, %	24,6*	—	24,4	25,3

(7) * *Включая крыло, фюзеляж, шасси, оперение и гондолы двигателей.*

Key:

1. Characteristic
2. IL-62
3. Super VC-10
4. Boeing 707
5. Load ratio, %
6. Relative airframe weight
7. *Including wings, fuselage, gear, tail section and engine nacelles.

Let's recall that aircraft weight efficiency is characterized by the highest load ratio and the lowest value for relative airframe weight. Incidentally, the IL-62 would have had worse figures in this area than the DC-8 and Boeing 707 (with equal weight efficiency for the designs) if a fundamentally new landing gear design had not been found. As already mentioned, this was brought about by locating the engines in the rear of the fuselage which led to an improvement in a number of the airliner's characteristics but it also led to weighing down the airframe. Moreover, there was not only an increase in fuselage weight but also in the wings which were relieved of the engines.

The size of the weight increase was minimized by the methods cited above. To some extent, this is the reason the IL-62's load ratio has an advantage over the Super VC-10's ratio; the VC-10 also has an aft-mounted engine configuration (we cannot discuss the relative airframe weight for this aircraft since the corresponding figures have not been published).

In general, a high degree of structural weight efficiency can be achieved by thoroughly analyzing the weight, strength and various arrangements and configurations during all phases of aircraft planning and design, beginning with the preliminary design. During the initial period when the basic designs are being developed for aircraft components and various systems, the foundation is already being laid for the design of optimal load-bearing configurations and a thorough study of them is conducted during the design process. The achievement of this goal assists in selecting rational dimensions, a high degree of density in the layout for diverse cargo and equipment systems and also a feasible location for the latter based on a minimum length for service lines. The development of an efficient design is also facilitated by designing with the minimum weight, projecting the reduced loads and subsequently conducting static tests for the full, estimated payload.

Continuing our comparative evaluation, Table 6 shows data on the same type of aircraft (based on engine configuration), the IL-62 and the British Super VC-10. Moreover, these aircraft have the same approximate dimensions (as, incidentally, do the two other intercontinental airliners--the DC-8 and the Boeing 707); in addition, they were designed at almost the same time, i.e., they meet the same state of the art.

The table contains data on the basic version of the IL-62 with the NK-8-4 engines and the IL-62M modification to it. The latter differs in its increased range. The economic efficiency was increased by almost 10 percent. The IL-62 can fly non-stop from Moscow to New York with 120 passengers on board while the IL-62M will carry 170 passengers. Naturally, the empty weight also increased at the same time, especially since there was an increase in take-off weight.

The payload for all three aircraft is for the passenger version. The payload can be increased in the cargo-passenger version, with the payload being restricted by the aircraft's strength (or weight). For example, according to press reports, the payload for the cargo-passenger version of the Super VC-10, with five pallets stowed in the forward passenger compartment is 26,450 kg.

Table 6

	(1) Характеристика	(2) Ил-62	(3) Ил-62М	(4) «Супер» VC-10
(5)	Взлетный вес, кГ	161 600	165 000	152 000
(6)	Вес пустого снаряженного, кГ	69 400	71 600	71 500
(7)	Число пассажиров (максимальное)	186	186	163
(8)	Максимальный вес коммерческой нагрузки, кГ	23 000	23 000	21 060
(9)	Техническая дальность при максимальной нагрузке, км	7550	8800	8500
(10)	Максимальная техническая дальность, км	10 000	11 050	11 600
(11)	Коммерческая нагрузка при максимальной дальности, кГ	6000	10 000	6300
(12)	Крейсерская скорость, км/ч	850	870	886
(13)	Площадь крыла (полная), $м^2$	279,6	279,6	272,4
(14)	Площадь крыла (по трапеции), $м^2$	253,4	253,4	256
(15)	Удельная нагрузка на крыло (к полной площади), $кГ/м^2$	578	590	558
(16)	Энерговооруженность, кГ·тяги/кГ·веса	0,260	0,267	0,270
(17)	Весовая отдача, %	57,0	56,6	53,0
(18)	Производительная отдача, т·км/кГ	1,08	1,23	1,18

Key:

1. Characteristic
2. IL-62
3. IL-62M
4. Super VC-10
5. Take-off weight, kg
6. Empty weight, kg
7. Passengers (maximum)
8. Maximum payload, kg
9. Dry tank range with maximum payload, km
10. Maximum dry tank range, km
11. Payload for maximum range, kg
12. Cruising speed, km/hr
13. Wing area (gross) m^2
14. Wing area (trapezoidal)
15. Maximum wing loading (gross area), kg/m^2
16. Power-to-weight ratio, kg-thrust/kg-weight
17. Load efficiency, %
18. Productivity efficiency, %

The number of passengers shown in Table 6 is for the full-size galley unit configuration. When part of the galley unit is removed, the number of passengers for the Super VC-10 increases to 174. The similar configuration for the IL-62 makes it possible to put in an additional two rows of seats and increase the number of passengers to 198.

Along with other Soviet aircraft, the IL-62, the flagship of the Soviet Union's Aeroflot (as it is now commonly called), has been shown at international aerospace shows in Paris in 1965 and 1967 and also in Turin in 1968. The visitors' noteworthy comments and questions on this aircraft were preserved in a book. For example, during the last show, Gen Alessandrini, the fly-by commander, wrote after visiting the IL-62: "I was delighted by the mighty ships and the warm reception from the Russian aviators."

The comments of crews from foreign countries who have flown on the IL-62 are especially interesting. Here is one of these comments: "When we got acquainted with the documentation, we were surprised at the IL-62's exceptional flying characteristics. We even requested that the chief aerodynamics specialist from Il'yushin's Experimental Design Bureau be sent TDY to us; he explained things to us for two whole days. The most experienced men among us were prepared to test the VC-10 and then the IL-62. With full responsibility, I can state that the IL-62 is even better than it was described to us or than it is shown in the engineering materials sent from the USSR."

This observation not only describes the merits of the IL-62 but also an accepted rule of ours: never put any advertising in the technical documentation (including the preliminary designs) which cannot be realized. It is better when the actual values obtained for the various characteristics not only match but surpass the design characteristics.

In commenting on the Prague-London flight, the British magazine AEROPLANE (7 August 1968) wrote: "After the engines were started, the noise from them was barely audible. The take-off took 35 seconds. Throughout the entire flight, the aircraft was as stable as a rock and it absolutely did not show any tendency to vibrate as is typical of large aircraft with a long nose section. The operation of the air brakes and flaps was hardly perceptible and only a slight thump was heard when the gear was extended at a rather high speed near Watford. But, this thump was a lot weaker than the one on, for example, the Boeing-720 during the same operation. The approach and landing speeds were fairly low and it seemed like the aircraft was floating in the air for a short time before final touch-down. There were no problems taxiing."

The American magazine AVIATION WEEK AND SPACE TECHNOLOGY (22 July 1968) wrote: "The opening of direct air communications between Moscow and New York last week again demonstrated that Aeorflot has acquired the ability to compete with international airlines on long-range routes. There is no doubt that it can proceed on a par with the leading western airlines.

"The IL-62 has proven its efficiency, both in the sense of engineering performance and basic passenger comfort. The aircraft was really quiet and comfortable in flight. The flexible wing took most of the load from the turbulence and the passengers hardly felt the turbulence when the aircraft went through air pockets. Also, there was no vibration in the rear part of the fuselage as there is in certain other jet airliners."

CHAPTER 19

GROUND ATTACK AVIATION IN THE PATRIOTIC WAR*

As soon as man's thought developed the aircraft, the general staffs of the armies in all countries immediately turned their attention to this new type of equipment in order to use it for the needs of war.

The Wright brothers made the first flight in an aircraft in December 1903; 8-9 years later, aircraft were already being used in the war in Tripoli between Turkey and Italy and also in the war between the Balkan Alliance and Turkey.

During World War I, 1914-1918, aircraft played a noticeable role in ground army operations. The armies used aircraft as scouts and bombers. Fighters appeared as a military weapon along with reconnaissance aircraft and bombers.

With the subsequent development of aircraft, their flying performance, specifications and combat performance were improved: their load-carrying capacity, range, speed and weapons systems increased.

Due to the exceptionally swift development of aircraft and the quantitative growth in military air forces after the 1914-1918 World War, statements about the decisive importance of aviation in future wars began to appear. Certain military men, for example, Italian Gen Douhet, advanced the theory in 1921 that the air force would be important on its own in future wars and that the air forces alone could decide the outcome of a war between states by bombing cities and vitally important centers.

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* Printed in PRAVDA, 18 August 1944

In our country, Gen Douhet's theory was renounced as being unwarranted and mistaken. We believed that military air forces would be very important as a weapons command for the ground army in any war in the immediate future and that air forces would carry out independent bombing operations against vital centers in the enemy's rear but they would not be able to independently decide the outcome of a war.

The experience of World War II has proven that our point of view was correct. The outcome of the war is being decided by large armies equipped with all types of modern equipment, including aircraft.

The experience of World War II has shown that, while accomplishing independent operations, aircraft can deliver appreciable strikes against the enemy's heartland, weakening his military posture. However, these operations are a long way from deciding the outcome of the war. Nevertheless, there are still certain air force representatives who believe that the air force can decide the outcome of World War II on behalf of the Allies by bombing the cities of the Axis countries.

It was clear to us that air forces would primarily be used in joint operations with land armies and the navy. Therefore, our design ideas were directed at ensuring that aircraft would be able to render the most effective assistance to the Red Army's land forces.

Based on what has been said, I was faced with a problem: designing an aircraft which could be used most fully and effectively by the Red Army in its operations. The environment in which an aircraft would have to operate and the targets which it would have to destroy resulted from this clear, simple formulation. The targets would be the enemy's men and equipment: tanks, motor vehicles, all artillery, machine gun nests, engineered structures, etc. For this purpose, the aircraft would have to be armed with various weapons systems: machine guns, cannons, bombs (of various sizes) and also rocket launchers.

In order to search out and effectively destroy small targets on the ground, such as, men, tanks, motor vehicles, individual gun crews and machine gun crews, which were, moreover, camouflaged, the aircraft would have to fly very close to the ground--at an altitude of 10-500 m. At high altitudes, it would be very difficult to search out and effectively destroy small targets.

But, while flying low above the ground, the aircraft would come under strong fire from enemy ground forces and this would force it to abort its attack. The second basic requirement for the aircraft flowed from this: make it an armored aircraft.

It was completely obvious that it was not possible to armor plate the aircraft against all the weapons which could fire against it from the ground since even tanks, with their very thick armor, can be penetrated by the appropriate size of ground artillery.

A serious problem appeared: on the one hand, it was necessary to select armor with a thickness which would not deprive the aircraft of good maneuverability and flying performance with its weight and, on the other hand, it was necessary for the armor to be able to protect the aircraft against concentrated enemy small arms fire, i.e., to make the aircraft invulnerable to rifle and machine gun fire and partially invulnerable to small-caliber cannon fire.

Thus, in time, the Il'yushin-2 ground attack aircraft appeared. The experience of the war has shown that the aviation engineering incorporated in the IL-2 is fully and effectively serving our glorious Red Army.

The most modern military equipment produced in small quantities cannot play a significant part in a war like the present one. Therefore, when I designed the IL aircraft, I took all the steps possible to make the aircraft simple in design and suitable for large-scale series production and also simple and accessible for large-scale operational use in a combat environment.

There was not only a problem in setting up mass production of these aircraft but also in setting up a new type of production for stamping the difficult aircraft armor which formed the foundation of the IL-2's armored hull.

In spite of the doubts expressed on the feasibility of setting up and developing production of these armored hulls, Comrade Zasul'skiy, the director of the Plant imeni Sergo Ordzhonikidze, and Comrades Svet and Sklyarov, his immediate assistants, honorably handled the technical side of the job and quickly set up mass production of the IL-2 armored hulls.

At that time, the job of developing and putting the IL-2 into series production was assigned to one of the best enterprises in the People's Commissariat for the Aviation Industry--the Plant imeni K. Ye. Voroshilov. Four months after receiving the blueprints, the plant had already set up series production of the ground attack aircraft.

The plants building the IL-2's were evacuated to the eastern regions of the country in 1941. The relocation of such giants was a very difficult job in itself. But, it was even more difficult to set up production in a new location. The intensely cold weather, snow and blizzards accompanied the reconstitution of the plants at their new locations. Two months after the plants were evacuated, the IL-2's were again heading for the front.

During the war, fascist Germany tried to develop its own ground attack aircraft: thus, for example, it tried to convert the Henschel-129 into a ground attack aircraft. But, as we all know, nothing came out of this venture.

The Soviet IL-2 ground attack aircraft are combat aircraft which operate most effectively in joint operations with land forces. There are no aircraft like the IL-2 in service with the other armies.

Our allies are using the Hurricane, Thunderbolt and a number of other fighters as ground attack aircraft; but, these aircraft cannot be compared to the IL-2 in combat effectiveness.

The IL-2 is a new type of aircraft. It will exist as long as large armies exist. We will strive to ensure that this type of ground attack aircraft will never be surpassed by our enemy. Soon, the enemy will feel the blows from new ground attack aircraft on his back; these aircraft are a lot more modern than the present ones.

Each day, news arrives from the front lines of the Patriotic War about how our pilots are helping our ground forces rout the enemy in the IL-2's. They are destroying thousands of fascist tanks and motor vehicles, hundreds of trains and hundreds of thousands of Germans. During the war, the IL-2 has also been widely employed at sea in modern operations with the navy. For this, the Germans call our ground attack aircraft "the black death."

APPENDICES

CHRONOLOGY OF IMPORTANT EVENTS IN S. V. IL'YUSHIN's LIFE AND WORK

Year	
1894	Son, Sergey, born into the family of Vladimir Ivanovich and Anna Vasil'yevna Il'yushin on 31 March in the Village of Dilyaleva, Vologodskaya Guberniya, Vologodskiy Uyezd, Berednikovskaya Volost'.
1901 1904	Studied at the county school in Beredniki.
1909	Began his work at Yakovlevskaya Factory near Kostroma
1910 1911	Worked in Peterburg at the Berta Plant, the Semennikovskiy Plant and Kolomyazhskiy Airfield. First introduction to aviation.
1912	Worked on the construction of the Amur Railroad.
1913 1914	Worked in Revel' (Tallin) building the Russo-Baltic Company Plant.
1914 1916	Army service: with a training detachment and an airfield detachment at Komendant Airfield in Peterburg. First flights on an aircraft.
1917	Completed flying school at Komendant Airfield. S. V. Il'yushin became a member of the airfield's revolutionary committee.

1918	Demobilized. Job at the Vologodskiy Council of People's Management as director of an industrial section. Entered the party. Took part in setting up the party cell at the teaching institute.
1919 1920	Served in the Red Army as a mechanic on the 6th Aviation Train, as commissar of the Caucasus Front's Second Aircraft Depot and chief of the Kuban' Army's 15th Aviation Train.
1921	Enrolled in the Red Air Force Engineering Institute imeni N. Ye. Zhukovskiy.
1923	Built the Mastyazhart training glider. Participated in the First National Glider Pilot Meet in Koktebel'.
1924	Built the Workers' School Student glider.
1925	Built the Moscow Glider and it participated in the competitions in Germany (pilot, K. K. Artseulov).
1926	Graduated from the Workers and Peasants Red Army Air Force Academy imeni Professor Ye. Zhukovskiy and commissioned as an air force mechanical engineer.
1926	Worked as chief of the first section of the AF Technological Committee.
1931	Participated in the National glider competitions as chairman of the Engineering Committee. Job as assistant chief for scientific and engineering affairs at a Scientific Research Institute.
1931 1933	Worked as chief of the Central Design Bureau (CDB).
1933	S. V. Il'yushin was in charge of the design team for a long-range bomber. Received his first decoration--the Order of the Red Star.
1936	First flight of the CDB-26. Demonstration of the CDB-26 during the fly-by at Red Square. The design team for the CDB-26 was renamed the Experimental Design Bureau (EDB). Developed the CDB-30. Set five world records lifting a payload to altitude in CDB-26.

1937 The CDB-30 put into service under the designation LRB-3. Began work on a ground attack aircraft design. Set world record for range in the LRB-3 along the route Moscow--Sevestopol'--Sverdlovsk--Moscow (see Table 1, p. 269). S. V. Il'yushin awarded the Order of Lenin and elected as a deputy to the USSR Supreme Soviet for the first time.

1938 Built the two-seat CDB-55 (LGA-2) [large ground attack aircraft] and the CDB-32 fighter. The LRB-3 modified as the LRB-3F. Record breaking flight in the Moscow along the route Moscow--Spassk (Far East).

1939 Record breaking flight along the route Moscow--St Lawrence Island (North America) in the Moscow. S. V. Il'yushin awarded the Order of the Labor Red Banner and elected as a deputy to the Moscow Council of Workers Deputies. Began testing the LGA-2.

1940 LRB-3F bomber renamed the IL-4. S. V. Il'yushin awarded the doctor of engineering sciences degree. First flight of the single-seat CDB-57 (LGA-1) ground attack aircraft. Start of series production of ground attack aircraft.

1941 State Tests of the CDB-57 and its acceptance for service under the IL-2 designation. S. V. Il'yushin awarded the title Hero of Socialist Labor, the Order of Lenin, the Hammer and Cycle Gold Medal and the State Prize.

1942 Series production of the two-seat IL-2 ground attack aircraft. S. V. Il'yushin awarded the State Prize. The EDB headed by S. V. Il'yushin decorated with the Order of Lenin.

1943 Design work on the IL-12. S. V. Il'yushin awarded the State Prize.

1944 The IL-8 ground attack aircraft built and turned over for testing. The IL-10 ground attack aircraft was built, underwent State Tests and was put into series production. S. V. Il'yushin was awarded the Order of Suvorov, second degree, and the Order of the Red Banner and promoted to the rank of Lieutenant General in the Aviation Engineer Corps. The EDB decorated with the Order of the Red Banner.

1945	The IL-16 ground attack aircraft was built, underwent State Tests and was put into series production. The IL-12 airliner was built. S. V. Il'yushin was decorated with two Orders of Lenin and an Order of Suvorov, first degree.
1946	First IL-12 flight. The IL-22 experimental bomber was built and underwent testing. S. V. Il'yushin was awarded the State Prize.
1947	First flight of the IL-18 airliner (with piston engines). S. V. Il'yushin awarded the State Prize.
1948	First flight of the IL-28 bomber. The IL-20 ground attack aircraft and the IL-32 military transport glider were built. S. V. Il'yushin awarded the title of professor.
1950	S. V. Il'yushin decorated with the Order of Labor Red Banner and awarded the State Prize.
1951	The IL-30 experimental bomber was built.
1952	First flight of the IL-46 experimental bomber; S. V. Il'yushin awarded the State Prize.
1953	The IL-40 experimental ground attack aircraft was built and tested.
1954	The IL-54 experimental bomber was built and tested. S. V. Il'yushin was decorated with the Order of Lenin.
1957	The IL-18 airliner (with turbo-prop engines) was built and launched. S. V. Il'yushin was decorated with the Order of Lenin and his second Hammer and Cycle Gold Medal.
1958 1959	The IL-18 set a number of world records for turbo-prop aircraft in speed and lifting a payload to altitude.
1960	Lenin Prize awarded for the development of the IL-18 to S. V. Il'yushin and his co-workers at the EDB, V. A. Borog, V. M. Germanov, V. K. Kokkinaki, A. Ya. Levin, Ye. I. Sankov, V. N. Semenov.
1963	First flight of the IL-62 prototype.

1964 Decorated with the Order of Lenin.

1967 Scheduled passenger service on the IL-62.

1968 Elected a full member of the USSR Academy of Sciences.

1969 S. V. Il'yushin decorated with the Order of the October Revolution. The EDB decorated with the Order of the Labor Red Banner.

1970 Lenin Prize awarded for the development of the IL-62 airliner to EDB personnel G. V. Novozhilov, Ya. A. Kutepov, V. I. Smirnov, D. V. Leshchiner, V. M. Sheynin, V. N. Ovcharov.

1974 Awarded the Order of Lenin and the third Hammer and Cycle Medal.

1977 On 14 January, bust of thrice-honored Hero of Socialist Labor Sergey Vladimirovich Il'yushin uncovered in Vologda.

1977 S. V. Il'yushin passed away on 9 February.

A chronology of some of the events related to the creative work of S. V. Il'yushin's EDB group after he resigned his duties as manager is provided below.

1971 First flight of the IL-62 cargo aircraft designed by G. V. Novozhilov.

1976 First flight of the IL-86 wide-bodied aircraft (Airbus) designed by G. V. Novozhilov.

1977 On 16 September, a female Aeroflot crew--I. Vertiprakhova, Ye. Martova, T. Pavlenko, G. Kozyr', G. Smagina, N. Kostyrkina--flew the IL-62M a distance of 5,019 km at a speed of 975 km/hr along the closed circuit Moscow--Simferopol'--Sverdlovsk--Moscow. This was a new record for speed in a closed circuit.
On 22 September, the same female crew set two world-class records in the IL-62M. The first was for range: they flew non-stop along the route Moscow--Simferopol'--Sverdlovsk--Moscow, covering a distance of 10,355 km. The second was for sustaining an average speed of 804 km/hr for a distance of 10,000 km.

LIST OF WORLD RECORDS AND OUTSTANDING FLIGHTS SET IN AIRCRAFT DESIGNED BY S. V. IL'YUSHIN

Tables 1 and 2 below show data on significant flights and world records set at various times in standard (series) aircraft. In other words, these aircraft were not and are not record-breaking aircraft, i.e., designed for the purpose of achieving these records. They are either combat aircraft or conventional civilian aircraft which were developed to accomplish their role in the best possible manner.

The records were made by test pilots V. Kokkinaki, Ya. I. Vernikov and A. M. Tyuryumin and also by pilots B. M. Konstantinov and L. M. Ulanova; the majority of them are current as of 1976.

Table 1. Significant Flights in Aircraft Designed by S. V. Il'yushin

(1) Маршрут	(2) Дата перелета	(3) Тип самолета	(4) Экипаж	(5) Нагрузка, кг	(6) Протяженность, км	(7) Скорость полета, км/ч	(8) Продолжительность полета
(9) Москва — Севастополь — Свердловск — Москва	(10) Август 1937 г.	(11) ДБ-3 (Ил-4)	(12) В. Коккинаки А. Брандинский	1000	5018	325	
(13) Москва — Спасск (район Владивостока)	(14) 27 июня 1938 г.	ДБ-3 (Ил-4)	В. Коккинаки А. Брандинский	—	7580	307	24 ч (a) 36 мин (b)
(15) Москва — Северная Америка (залив Св. Лаврентия) через Атлантический океан и Гренландию (беспосадочный) *	(16) 28 апреля 1939 г.	ДБ-3 (Ил-4) «Москва»	В. Коккинаки А. Брандинский Н. Гордиенко (17)	—	8000	348	22 ч 56 мин
(18) Москва — Сиэтл (США, штат Вашингтон) через Северный полюс **	(14) Июнь 1975 г.	Ил-62М	(19) А. Витковский (командир)	—	9480		10 ч 54 мин

* За этот полет В. Коккинаки награжден бриллиантовым ожерельем ФАИ. (20)

** Повторен маршрут, проложенный В. П. Чкаловым в 1937 г. (Москва — Ванкувер, время полета 63 ч 25 мин). (21)

Key:

1. Route
2. Date
3. Aircraft
4. Crew
5. Payload, kg
6. Distance, km
7. Speed, km/hr
8. Duration
   a) hr
   b) min
9. Moscow-Sevastopol'-Sverdlovsk-Moscow
10. August
11. LRB-3 (IL-4)
12. V. Kokkinakki, A. Bryandinskiy
13. Moscow-Spassk (Near Vladivostok)
14. June
15. Moscow-North America (St. Lawrence Island) via Greenland and the Atlantic Ocean (non-stop)*
16. April
17. N. Gordenko
18. Moscow-Seattle (Washington State, U.S.) via the North Pole**
19. A. Vitkovskiy (captain)
20. * V. Kokkinaki was awarded the FAI diamond necklace for this flight.
21. **A repeat of the route flown by V. P. Chkalov in 1937 (Moscow-Vancouver; flight time 63 hr 25 min)

Table 2. World Records Set in Aircraft Designed by S. V. Il'yushin

ЦКБ-26 (1)

1936 г. (В. К. Коккинаки) (3)		*Высота с грузом, м — т* (2)
	17.VII	11 294—0,5
	26.VII	11 747—1
	3.VIII	12 816—0,5
	3.VIII	13 178—0,5
	21.VIII	12 101—1
	7.IX	11 005—2
1937 г. (В. К. Коккинаки) (3)	26.VIII	*Скорость на дальность 5000 км 325,257 км/ч* (4) *без груза и с грузами, т* 0,5; 1
	26.VIII	*Дальность по замкнутому маршруту 5018,2 км* (5)

ИЛ-18

1958 г. (В. К. Коккинаки) (3)	14.XI	*Высота с грузом *, м — т* (2) 12 471—15
	15.XI	13 154—10
	17.XI	13 274—5
1959 г. (В. К. Коккинаки) (3)	19.VIII	*Скорость при дальности 2000 км* (4) *719,496 км/ч с грузами, т* 1; 2; 5; 10; 15
	25.XI	*Высота с грузом *, м — т* (2) 12 118—20; 2 000—20,114
1960 г. (В. К. Коккинаки) (3)	2.II	*Скорость при дальности 5000 км* (4) *693,547 км/ч без груза и с грузами, т* 1; 2; 5; 10
1967 г. (Л. М. Уланова) (7)	14—15.X	*Дальность по прямой 7661,949 км ** (6)
	20.X	*Высота 13 513 м* (8)
1968 г. (В. М. Константинов) (11)	6.V	*Скорость на базе 15—20 км 727,840 км/ч* (9)
		*Скорость по замкнутому маршруту 100 км 786 км/ч ** (10)
1969 г. (Л. М. Уланова) (7)	12.VII	*Скорость при дальности 5000 км 701,068 км/ч ** (4)
	13.VII	*Высота горизонтального полета 12 990 м ** (12)
	18—19.VII	*Дальность по замкнутому маршруту 8023,153 км ** (5)

ИЛ-76

1975 г. (Я. И. Верников) (13)	4.VII	*Высота 11 875 м с грузом, т* * (14)
		60
		65
		70
	4.VII	*Груз 70 121 кг на высоту 2000 м* * (15)
(А. М. Тюрюмин) (17)	4.VII	*Скорость при дальности 2000 км* * (16) *856, 697 км/ч с грузом, т* *
		35
		40
		45
		50
		55
		60
		65
		70
1975 г. (А. М. Тюрюмин) (17)	7.VII	*Скорость при дальности 1000 км 857,* (16) *657 км/ч с грузом, т* *
		30
		35
		40
		45
		50
		55
		60
		65
		70
1975 г. (А. М. Тюрюмин) (17)	10.VII	*Скорость при дальности 5000 км* * *815,* (16) *968 км/ч с грузом, т* *
		15
		20
		25
		30
		35
		40

Примечание. Звездочками отмечены действующие рекорды. В первой графе, в скобках, указаны командиры кораблей. (18)

Key:

1. CDB-26
2. Altitude and weight, meters-tons
3. V. K. Kokkinaki
4. Speed for---km distance, ---km/hr, with and without weight, tons
5. Distance in a closed circuit
6. Distance in a straight line
7. L. M. Ulanova
8. Altitude
9. Speed for a 15-20 km course
10. Speed in a closed circuit
11. B. M. Konstantinov
12. Altitude for level flight
13. Ya. I. Vernikov
14. Altitude _____ and weight, tons
15. Weight _____ to altitude _____
16. Speed for _____ km distance, with weight, tons
17. A.M. Tyuryumin
18. Note: Asterisks denote current records. Aircraft captains are shown in parentheses in the first column

BASIC SPECIFICATIONS FOR AIRCRAFT DESIGNED BY S, V. IL'YUSHIN

Incomplete, at times contradictory and sometimes even distorted data on domestic aircraft are encountered in various popular science books. This is based on the authors' insufficient information or misunderstanding and incorrect interpretation of aircraft performance. For example, it is believed that maximum payload and maximum range are comparable performance characteristics, i.e., they do not take into account the dependence of range on payload. Therefore, to provide reliable information and a correct understanding, we thought it would be useful to put some reference data on aircraft designed by S. V. Il'yushin and on their weapons systems in an appendix:

1. Two-seat, single engine ground attack aircraft--with piston engines (Table 1);
2. The bombs, guns and armor plating for ground attack aircraft (Table 2);
3. Bombers (Table 3);
4. Airliners (Table 4).

Table 1. Two-seat, Single Engine Ground Attack Aircraft (with Piston Engines)

	(1) *Характеристика*	*Ил-2*	*Ил-8*	*Ил-10*	*Ил-16*	*Ил-20*
(2)	Год выпуска 1-го серийного самолета	1940	—	1944	1945	1948
(3)	Дата 1-го вылета	1939	1944	1944		
(4)	Тип двигателя	АМ-38Ф	АМ-42	АМ-42	АМ-43НВ	МФ-47
(5)	Мощность двигателя, л. с.	1760	2000	2000	2300	3000
(6)	Площадь крыла, $м^2$	38,5	39,0	30,0	24,0	44,0
(7)	Размах крыла, *м*	14,6	14,6	13,4	12,5	17,0
(8)	Длина самолета, *м*	11,65	12,93	11,12	10,19	12,59
(9)	Высота самолета, *м*	2,95	3,4	3,0	3,885	4,1 (без винта) (10)
(11)	Колея шасси, *м*	3,5	3,5	3,0	3,05	4,35
(12)	Взлетный вес, *кГ*					
	(a) нормальный	6060	7210	6300	5400	9930
	(b) перегрузочный	6360	7610	6500	5600	10250
(13)	Вес пустого самолета, *кГ*	4530	5176	4650	4150	7892
(14)	Вес бомбовой нагрузки, *кГ*					
	(a) нормальный	300	600	400	200	400
	(b) перегрузочный	600	1000	600	400	1000
(15)	Максимальная дальность полета, *км*	800	1140	800		1680
(16)	Максимальная скорость полета, *км/ч*	400	509	550	625	515
(17)	Потолок, *м*	5440	6900	7250	9000	7750

Key:

1. Characteristic
2. First series produced aircraft
3. Date of first flight
4. Engine
5. Engine power, h.p.
6. Wing area, m^2
7. Wing span, m
8. Aircraft length, m
9. Aircraft height, m
10. Without propeller
11. Wheel track, m
12. Take-off weight, kg
    a) normal
    b) overload
13. Empty weight, kg
14. Bomb load, kg
    a) normal
    b) overload
15. Maximum range, km
16. Maximum speed
17. Ceiling, m

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Table 2. Bombs, Guns and Armor for Ground Attack Aircraft

(1) Самолеты	(2) Средства атаки											(14) Средства обороны								(16) Отношение веса брони к весу пустого самолета
	(3) Бомбовое вооружение		(6) Стрелково-пушечное вооружение									(15) Турельная установка								
			пулеметы (7)					пушки (8)				пулеметы (7)				пушки (8)				
	(4) вес бомб, кг	(5) число реактивных снарядов (РС)	(9) число	(10) марка	(11) калибр, мм	(12) боезапас, шт.	(13) вариант вооружения	(9) число	(10) марка	(11) калибр, мм	(12) боезапас, шт.	(9) число	(10) марка	(11) калибр, мм	(12) боезапас, шт.	(9) число	(10) марка	(11) калибр, мм	(12) боезапас, шт.	
Ил 2	400 600 *	4 8	2	ШКАС (18)	7,62	1500	1 2 3	2 2 2	ШВАК (19) ВЯ (20) 11П	20 23 37	500 300 100	1	УБТ (21)	12,7	150	—	—	—	—	0,21
Ил-8	600 1000 * 400 800 *	—	2	ШКАС (18)	7,62	1500	1 2	2 2	ВЯ (20) 11П	23 37	300 100	1	УБТ (21)	12,7	150	—	—	—	—	0,21
Ил-10	400 600 *	4 8	2	ШКАС (18)	7,62	1500	1 2	2 2	ВЯ (20) 11П	23 37	300 80	— —	— —	— —	— —	1	УБ-20 (22)	20	150	0,21
Ил-16	200 400 *	—	2	ШКАС (18)	7,62	1500	—	2	115П	23	300	—	—	—	—	1	УБ-20 (22)	20	150	0,21
Ил 20	400 1000 *	4	—	—	—	—	—	4	Ш-3	23	600	—	—	—	—	1	Ш-3	23	200	0,21

* В перегрузочном варианте. (17)

Key:

1. Aircraft
2. Offensive weapons
3. Bomb systems
4. Bomb weight, kg
5. Number of rockets
6. Gun systems
7. Machine guns
8. Cannons
9. Number
10. Make
11. Caliber, mm
12. Rounds
13. Armament options
14. Defensive weapons
15. Turret Mount
16. Ratio of armor weight to empty weight
17. *Overload version
18. Shpital'nyy-Komarnitskiy rapid-fire machine gun
19. Shpital'nyy-Volkov cannon
20. Volkov-Yartsev cannon
21. Berezin general-purpose turret machine gun
22. Berezin general-purpose cannon

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Table 3. Bombers

(1) Характеристика	(2) ЦКБ-30	(3) ДБ-3	(4) Ил-4 (ДБ-3Ф)	Ил-6	Ил-22	Ил-28	Ил-46	Ил-54
(5) Год выпуска 1-го серийного самолета		1936 (23)				1948		
(6) Дата 1-го вылета	1936	Март 1936	1938	1943	1946	1948	1952	1954
(7) Число и тип двигателей	2ПД М-85 (24)	2ПД М-85	2ПД М-88Б	2 дизеля АЧ-30В (25)	4ТРД ТР-1 (26)	2ТРД ВК-1	2ТРД ТР-3А	2ТРД Ал-7
(8) Мощность двигателя, л.с.	850	850	1100	1500				
(9) Тяга двигателя, кГ	—	—	—	—	1300	2700		
(10) Площадь крыла, м²	65,6	65,6	66,7	84,8	74,5	60,8	105	84,6
(11) Размах крыла, м	21,44	21,4	21,44	26,0	23,06	21,45	27,75	17,65
(12) Длина самолета, м	14,223	14,223	14,79	17,65	21,05	17,65	24,5	28,964
(13) Высота самолета, м	4,15	4,15	4,67	5,44	7,4	6,2	8,815	
(14) Колея шасси, м	5,5	5,5	5,5	6,2	3,375	7,4	6,8	Велосип. шасси (27)
(15) Взлетный вес, кГ								
a) нормальный	6965	7000	8380	15 600	24 000	18 400		
b) перегрузочный		9000	11 300	18 650	27 300	21 200		
(16) Вес пустого самолета, кГ	5030	4778	5800	11 690	14 950	12 890		
(17) Вес бомбовой нагрузки, кГ								
a) нормальный	1000	1000	1000	2000	2000	1000	3000	3000
b) перегрузочный	2500	2500	2500	3000	3000	3000	6000	5000
(18) Максимальная дальность полета, км	4200	4000	3800	4000	865	2400	5000	2200—2400
(19) Максимальная скорость полета, км/ч	415	400	429	464	718	900	930	1150
(20) Потолок, м		8400	9700	7000	11 000	12 300	12 300	12 000—13 000
(21) Экипаж, чел.		3	3	6	5	3	3	3
(22) Вооружение								
a) пушки				(30) ШВАК; 20 мм, 5 шт.	НС-23; 23 мм, 2 шт. Б-20; 20 мм, 2 шт.	НР-23; 23 мм, 4 шт.	НР-23; 23мм, 4 шт.	ТКБ-4957; 23 мм, 2 шт.
b) пулеметы		(28) ШКАС; 7,62мм, 3шт.	ШКАС; 7,62мм, 3шт. УБТ; (29) 12,7мм, 1шт.		—	—	—	—

Key:

1. Characteristic
2. CDB-30
3. LRB-3
4. IL-4 (LRB-3F)
5. First series produced aircraft
6. Date of first flight
7. Number and type of engines
8. Engine power, h.p.
9. Engine thrust, kg
10. Wing area, m^2
11. Wing span, m
12. Aircraft length, m
13. Aircraft height, m
14. Wheel track, m
15. Take-off weight, kg
    a) normal
    b) overload
16. Empty weight, kg
17. Bomb load, kg
    a) normal
    b) overload
18. Maximum range, km
19. Maximum speed, km/hr
20. Ceiling, m
21. Crew
22. Weapons
    a) cannons
    b) machine guns
23. March
24. Piston
25. Diesel
26. Turbojet
27. Bicycle gear
28. Shpital'nyy-Komarnitskiy rapid-fire machine gun
29. Berezin general-purpose turret machine gun
30. Shpital'nyy-Volkov cannon

Table 4. Airliners

(1) *Характеристика*	*Ил-12*	*Ил-14*	*Ил-18А*	*Ил-18В*	*Ил-18Д*	*Ил-62*	*Ил-62М*
(2) Год выпуска 1-го серийного самолета	1946	1953	1957	1962	1965	1963	1969
(3) Двигатели							
a) число и тип	2ПД (7) АШ-82ФН	2ПД АШ-82Т	4ТВД (8) АИ-20А	4ТВД АИ-20К	4ТВД АИ-20М	4ТВлД (9) НК-8-4	4ТВлД Д30-КУ
b) мощность, л.с.	1850	1900	4000	4000	4250		
c) тяга, кГ						10 500	11 000
(4) Основные размеры самолета							
a) площадь крыла, м²	103	100	140	140	140	279,55	279,55
b) размах крыла, м	31,7	31,7	37,4	37,4	37,4	42,5	42,5
c) диаметр фюзеляжа, м	2,8	2,8	3,5	3,5	3,5	3,75×4,1	3,75×4,1
d) длина, м	21,31	22,31	35,9	35,9	35,9	53,12	53,12
e) высота, м	7,8	7,8	10,195	10,195	10,195	12,35	12,35
f) колея шасси, м	7,92	7,7	9,0	9,0	9,0	6,8	6,8
(5) Летно-технические характеристики самолета							
a) взлетный вес, кГ	17 250	17 500—18 000	59 200	61 200	64 000	161 600	165 000
b) вес снаряженного самолета, кГ	11 000 *	12 500	33 800	34 500	35 300	69 400	71 600
c) число пассажиров	27—32	36—40	75	89—100	100—110	168—186	168—186
d) максимальная коммерческая нагрузка, кГ	2620—3160	2970—3550	10 100	13 500	13 500	23 000	23 000
e) дальность полета при максимальной коммерческой нагрузке, км	2200	1100—1400	3800	3300	4300	7550	8800
f) коммерческая нагрузка при увеличенном запасе топлива, кГ	1050		7300	8600	6500	6000	10 000
g) максимальная дальность полета при увеличенном запасе топлива, км	3300	2150—2550	5600	5400	7100	10 000	11 050
h) крейсерская скорость полета, км/ч	320	350	650	650	650	850	870
i) экипаж, чел.	4	4	5	5	5	5	5

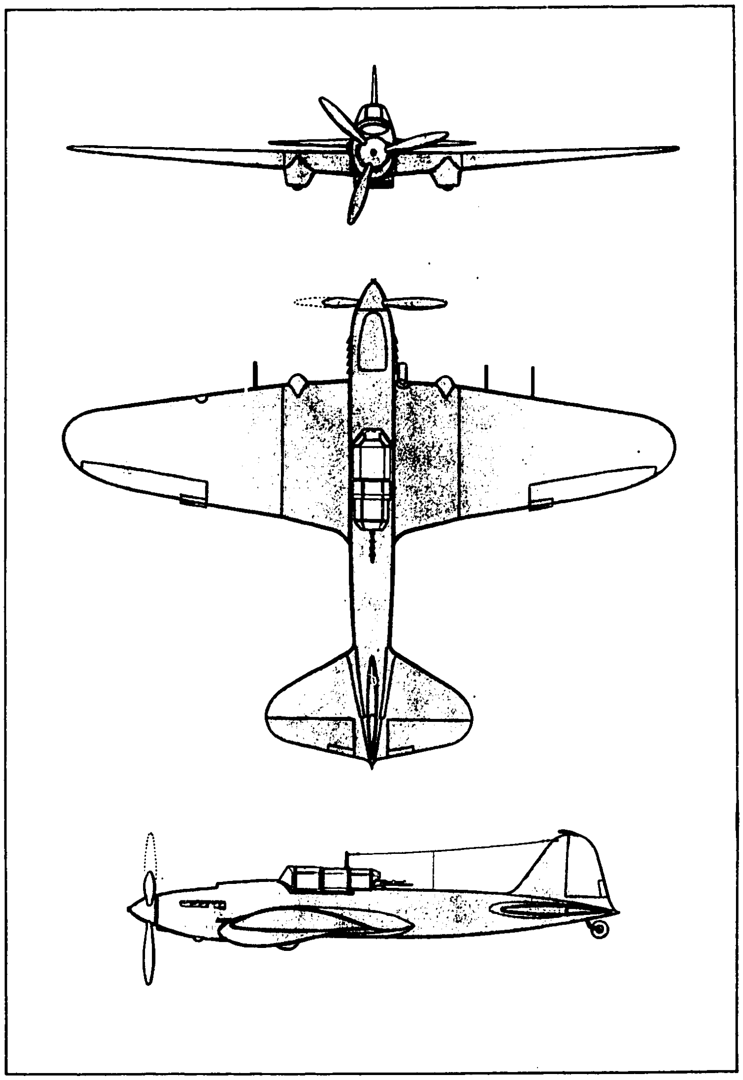
(6) * *Вес пустого самолета*

Key:

1. Characteristic
2. First series produced aircraft
3. Engines
   a) number and type
   b) power, h.p.
   c) thrust, kg
4. Dimensions
   a) wing area, m^2
   b) wing span, m
   c) fuselage diameter, m
   d) length, m
   e) height, m
   f) wheel track, m
5. Performance
   a) take-off weight, kg
   b) operating weight, kg
   c) passengers
   d) maximum payload, kg
   e) range with maximum payload, km
   f) payload with increased fuel reserves, kg
   g) maximum range with increased fuel reserves, km
   h) cruising speed, km/hr
   i) crew
6. *Empty weight
7. Piston
8. Turboprop
9. Turbofan

ILLUSTRATIONS OF AIRCRAFT DESIGNED BY S. V. IL'YUSHIN

The illustrations (pages 181-186) show overall views (in three views) of the main aircraft designed by S. V. Il'yushin; information on these aircraft was provided in the tables on pages 273-279. The latter include data on the basic versions and their primary modifications The illustrations only show the basic versions.



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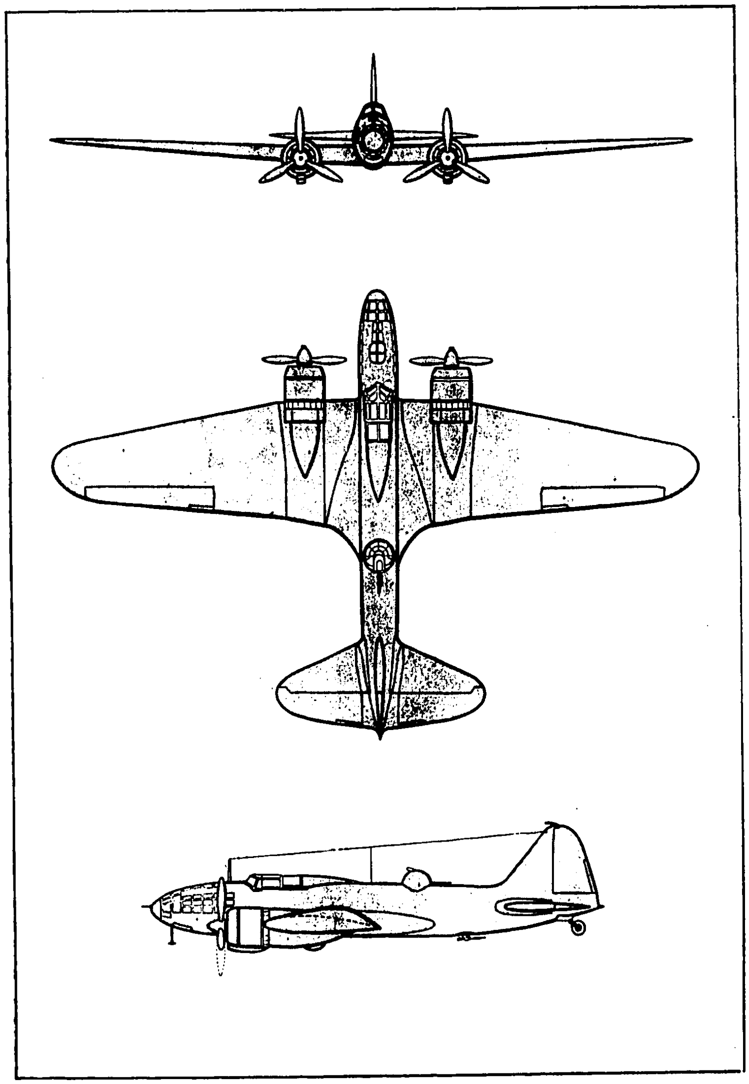

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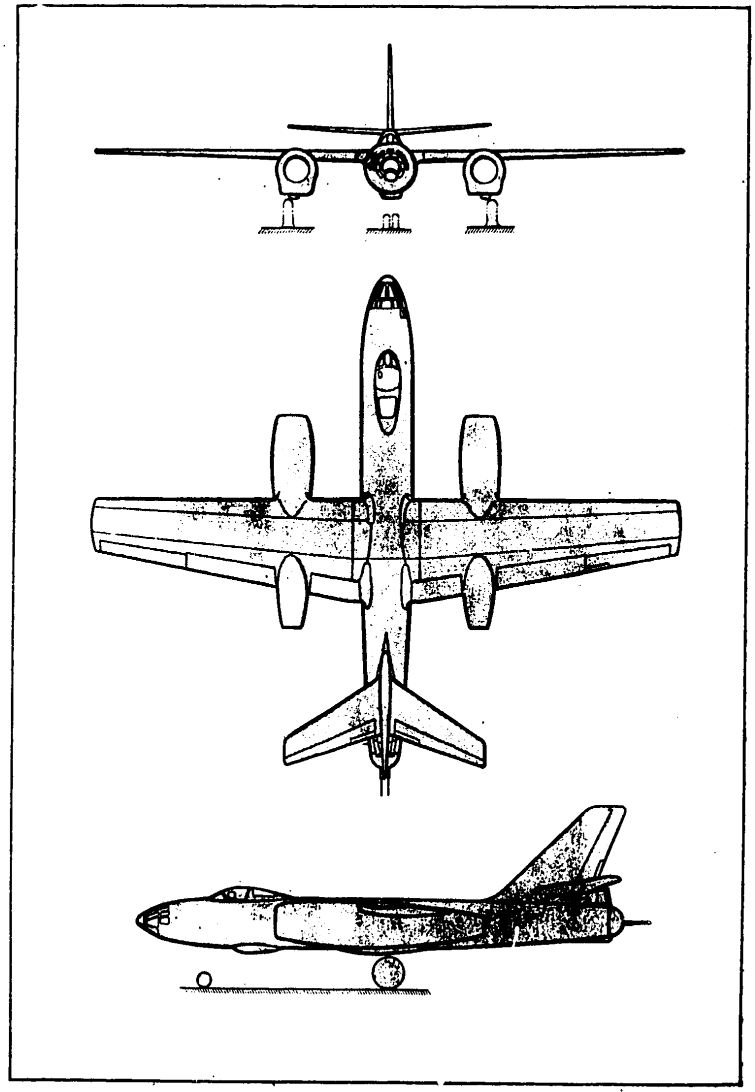

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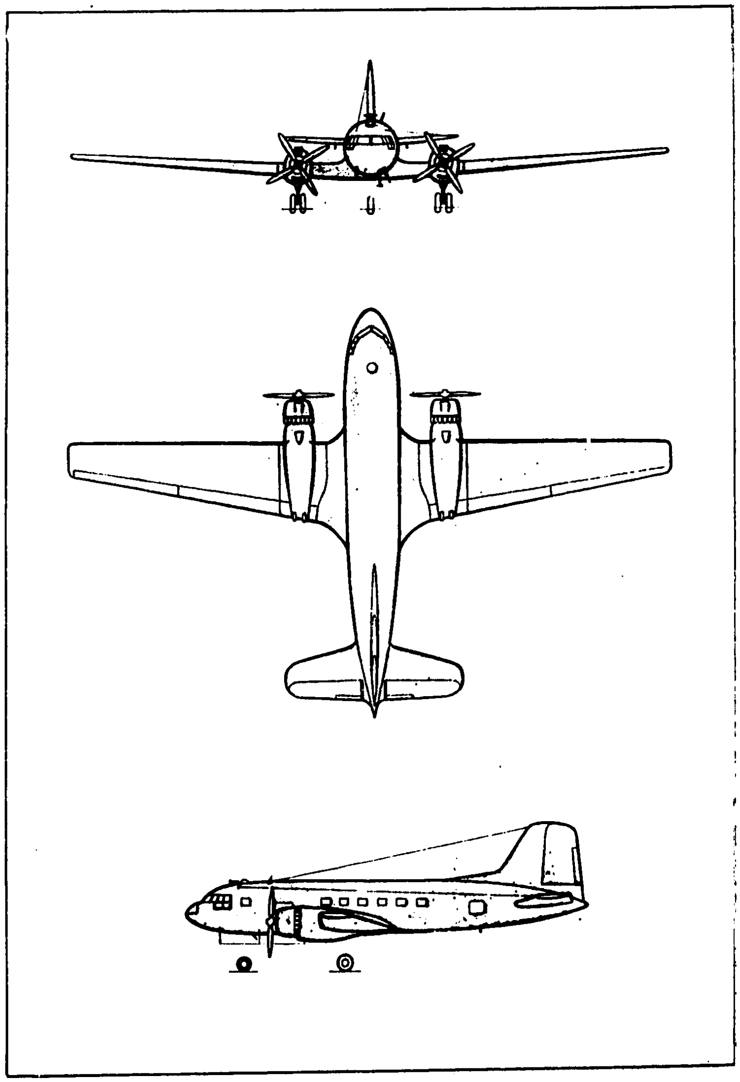

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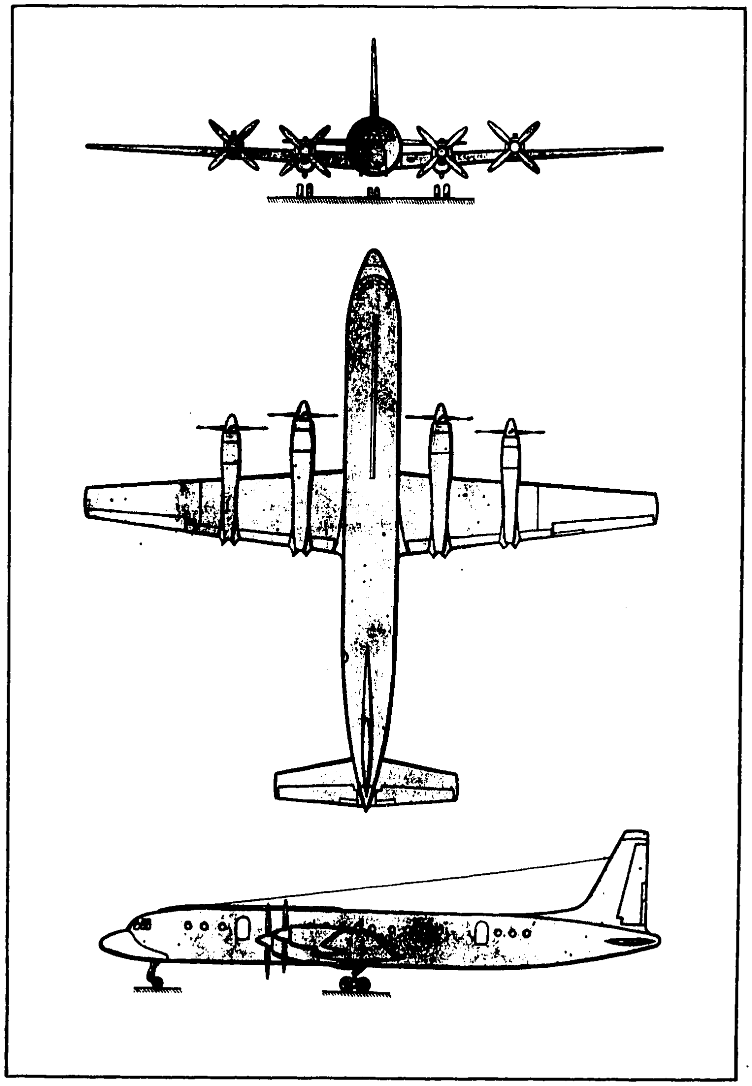

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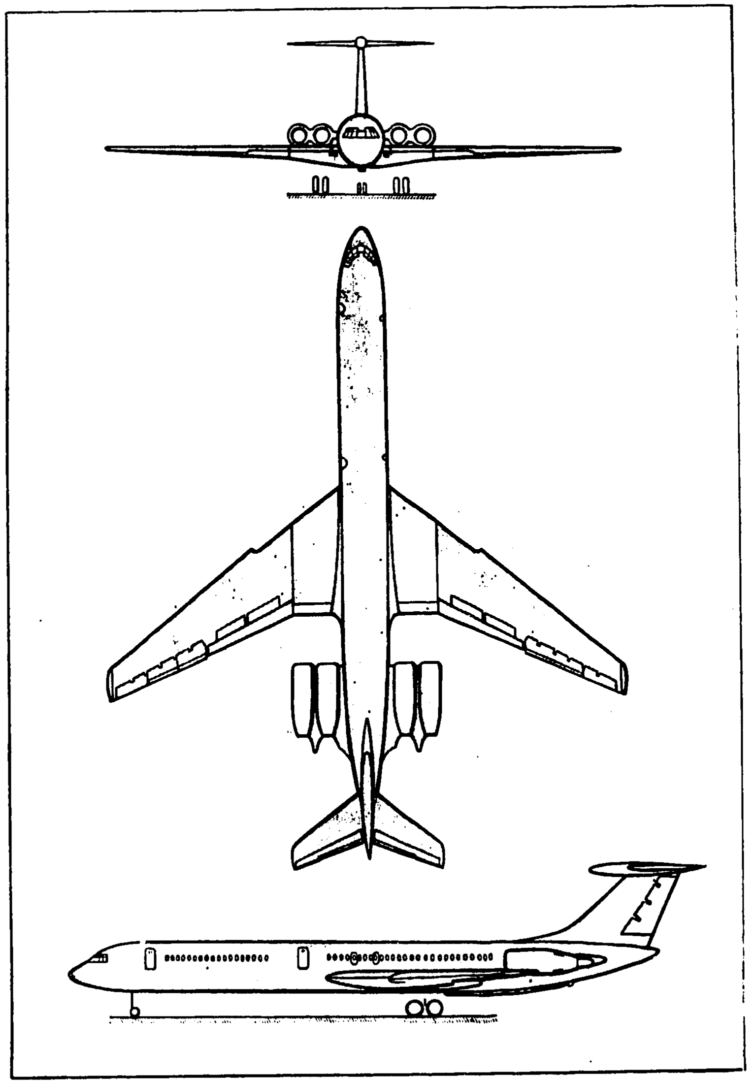

IL-62

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