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SOVIET AIRCRAFT ENGINE ACQUISITION

THESIS

Dale S. Gabriel, Captain, USAF

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SOVIET AIRCRAFT ENGINE ACQUISITION

THESIS

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Master of Science in Systems Management

Dale S. Gabriel, B.S.
Captain, USAF

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Preface

The purpose of this thesis was to develop an unclassified comprehensive review of the process by which aircraft engines are developed and acquired in the Soviet Union, and of the organizations involved at each phase. Also, the study was to determine whether this acquisition system is capable of satisfying Soviet national objectives. The USAF engine acquisition system was used as a basis for comparison.

The Foreign Technology Division provided most of the data on the Soviet process and organizations. Executives of the Aeropropulsion Laboratory and the Propulsion Systems Program Office greatly contributed to my understanding of the USAF engine acquisition system.

I would like to thank a number of people for their help. I greatly appreciate the guiding hand of my faculty advisor, Dr. Richard Taliaferro. I am deeply indebted to my former coworkers, Mr. Kim Williams and Captain Maria Schreffler, of the Foreign Technology Division for all the information that they provided. Finally, my warmest thanks go to my wife, Lynn, for her patience and support, especially after the birth of our son, David, during the writing this thesis.

Dale S. Gabriel

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Abstract

This thesis examined at the unclassified level the Soviet aircraft engine development and acquisition process, as well as the roles of the organizations involved. It also examined how well the Soviet system was capable of fulfilling Soviet national objectives. The U. S. Air Force engine acquisition system was used as a basis for comparison. The highly centralized Soviet weapon system acquisition process is currently controlled by the Communist Party of the Soviet Union. The Uniform System of Design Documentation mandates a series of development stages which must be performed. The development and acquisition of aircraft engines takes place entirely within the Soviet government: no private engine industry exists. Research, design/development, and production of Soviet aircraft engines are performed by separate organizations within the Ministry of Aviation Industry. The successful developments of large turbofans for transports and smaller turbofans for fighters indicate a significant capacity to produce advanced systems representing an increased military threat to United States forces in potential future conflict. The current industry restructuring efforts are moving the Soviet system closer to that employed by the U.S. Air Force.

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I. Introduction

General Issue

The aircraft is crucial to the conduct of modern warfare at all levels of conflict. The aircraft may serve as a weapon system itself, as a launch platform for weapons, or as a means to deliver weapons to the battlefield. Throughout a variety of missions, including strategic and tactical airlift, air interdiction, air superiority, aerial bombardment, close air support, and reconnaissance, extreme demands are made on the performance of the aircraft in the form of speed, maneuverability, and range. These performance characteristics are for the most part determined by the thrust and fuel consumption of the aircraft's engines. It is for this reason that many consider propulsion to be the "pacing technology" for advancement in aircraft development.

This thesis examines the ability of the Soviet aircraft engine industry to develop and acquire aircraft engines in order to provide military capabilities required by current doctrine in fulfillment of Soviet national objectives.

Although the focus of this thesis is on Soviet aircraft engine acquisition, the importance of successful engine development in achieving a predetermined military capability may be illustrated by anecdotal reference to U. S. Air Force (USAF) experience. Robert Drewes' The Air Force and the Great Engine War describes the development of the Pratt & Whitney F100 engine for the F-15 air superiority fighter. Faced with the likelihood of Soviet air superiority in the 1970s, Air Force planners decided the F-X aircraft (later to become the F-15) would be dedicated to the air-to-air combat role to counter the suddenly increased Soviet threat. Since maneuverability was the key to developing a superior fighter, significantly improved engine performance was required. The F-100's thrust-to-weight ratio of eight-to-one nearly doubled the performance of earlier engines, and allowed the F-15 to accelerate vertically. The powerful new engine enabled the F-15 to become the world's most advanced and capable air-superiority fighter.

Since any evaluation of Soviet acquisition processes must necessarily be subjective, current USAF engine development practices will be used as a basis against which the Soviet military engine development practices are compared later in this thesis.

In both the United States and the Soviet Union, highly complex procedures have been created and codified into law concerning the development and acquisition of major weapon systems like aircraft and subsystems like engines. In each country, the successful development and acquisition of such technologically advanced systems requires the integrated efforts of numerous organizations and extensive capital expenditures for a process usually lasting more than a decade. Many similarities exist between the two systems. Each system follows a general process of requirements generation and validation, research, design, development, test, production, and deployment. Also, both systems include milestone points at which approval decisions must be made for development work to continue.

While some similarities exist between the engine acquisition systems of the USAF and the Soviet military, the two systems nevertheless vary significantly in some ways. Different historical forces in the two nations have caused the evolution of different political and economic philosophies which shape the organizational structures and procedures for the development and acquisition of aircraft engines. The numerous military conflicts over the territory of what is now the Soviet Union over the last several centuries by, among others, the Mongols, the French, and twice by the Germans, have fostered an intense mindset of "defense of the homeland." The control of the economy and political system by the Communist Party of the Soviet Union over the last seven decades has resulted in a military industry very dissimilar from that found in the United States. In the Soviet Union, the central government, through different organizations, performs the individual tasks of research, design and development, and production in a process that, up to this point, has been controlled at every step by Communist Party central planners and bureaucrats. In the United States, one company may perform some of its own research and all of the design, development, and production in direct competition with other companies to win government contracts, with little governmental control over the resources available to each competitor or the methods to be used.

At this writing, dramatic changes appear to be taking place in the economy and polity of the Soviet Union. Perestroika, or "restructuring," and a new military doctrine of "reasonable sufficiency" combined with troop withdrawals from Eastern Europe and successful weapons reduction treaties, would seem to indicate a very different Soviet Union will exist in the 1990s. Soviet leaders state that a greater emphasis is being plac l on the nonmilitary sectors of the Soviet economy. This thesis includes an examination of the effects of such changes on the Soviet aircraft engine industry.

Problem Statement

At present, no single comprehensive analysis of the Soviet aircraft engine industry exists at the unclassified level to aid planners in the U. S. military and the American aircraft engine industry in understanding the process by which aircraft engines are developed and produced in the Soviet Union.

Research Objectives

The research objectives of this thesis are to examine and report whether the current structure of the Soviet aircraft engine industry appears to be capable of meeting relevant Soviet national objectives, and to examine what changes may be occurring in the system due to recent political and economic events. Since classified documents by their very nature have limited distribution, the intent of this thesis is to fill the unclassified knowledge gap through examination of the information that exists in the open press in both the United States and the Soviet Union.

Justification

The engine is perhaps the most critical subsystem on an aircraft. The propulsive force it produces largely determines the speed and performance of the aircraft, and its fuel efficiency is an important factor in determination of the aircraft's range. The speed, maneuverability, and range of Soviet military aircraft are used to evaluate the threat to U. S. and allied interests.

An understanding of the interrelationships of Soviet national objectives, of the organization of the Soviet aircraft engine industry, and of the process by which aircraft engines are developed in the Soviet Union, is necessary for determination by U. S. analysts of future military threats, and of possible civilian competition or even business opportunities. Despite the apparent lessening of tensions between the United States and the Soviet Union, the Armed Forces of the Soviet Union may still pose a threat to the national security and interests of the United States. While comprehensive analyses of the Soviet aircraft engine industry may exist at the classified level, such documents have limited distribution and create handling and storage difficulties for those with access to them. The purpose of this thesis is to provide interested parties in the U. S. government and the U. S. engine industry with a reliable foundation for understanding the Soviet aircraft engine industry based solely on generally available unclassified information.

Scope and Limitations

This thesis focuses specifically on how aircraft engines are designed, developed, tested, and produced in the Soviet Union, rather than merely describing the general weapons acquisition process. The thesis does not explore the advancement of Soviet engine technology. The findings of this thesis are based solely on unclassified material, including publications from the Department of Defense, U. S. intelligence agencies, aviation trade magazines, and where possible, from Soviet open press publications. The limited

Russian language capability of the author required a reliance upon secondary sources such as translations. Since no intelligence sources or methods have been used to verify the information obtained, no true measure of accuracy of the information may be given. Although comparisons with the engine acquisition process of the U. S. Air Force are made, the thesis does not describe the Air Force acquisition system in great detail.

II. Methodology

This section describes the general approach of the thesis research in order to provide an unclassified comprehensive analysis of the Soviet aircraft engine industry which might serve as a basis for discussion or for further research. The thesis examines Soviet national objectives as they pertain to military power projection, the weapon system acquisition process, and the organizations of Soviet industry and government which are involved in the development of aircraft engines.

The nature of the problem and the type of data examined precluded the use of statistical testing methods. Rather, an expository approach was used to describe the problem, present the available information, and provide an analysis of the Soviet engine acquisition system. First, a set of investigative questions was developed to control the direction and scope of the research regarding the type of information to be gathered. The focus of the effort was on the acquisition system (national objectives, the engine acquisition process, and relevant organizations) and not on the state of propulsion technology or capabilities in either the U. S. or the Soviet Union. This information enabled a description of relevant Soviet national objectives, of the Soviet engine acquisition process, and of the structure of the Soviet aircraft engine industry to be made. Using the engine acquisition process of the United States Air Force as a basis for comparison, the thesis discusses to what extent the current Soviet engine industry structure and the acquisition process seem to be capable of meeting national objectives. Because of the subjective nature of an analysis of such a system, some basis for comparison was required. With the U. S. Air Force engine acquisition system as that basis for comparison, the strengths and weaknesses of the Soviet system could be examined.

The investigative questions used to guide the research effort in examining Soviet aircraft engine acquisition were: What are current Soviet national goals regarding military capability, and how do these goals drive aircraft engine requirements? What is the process by which aircraft engines are developed and acquired in the Soviet Union? What is the organizational structure of the Soviet aircraft engine industry, and what are the relationships of the various organizations? What changes are affecting the Soviet system? What are the similarities and differences between the U.S. and Soviet military engine acquisition systems?

Historically, the Soviets have placed security classifications on nearly all information regarding their military operations, capabilities, and weapons systems, so that little such data were available to the general public. However, numerous experts observe and report on occurrences in the Soviet aerospace industry through analysis of primary sources like Russian publications and news broadcasts, making secondary sources like English translations of original Russian publications more plentiful than was originally believed by the author. Much of the information on Soviet defense-industrial organizations and the weapon system acquisition process used in this thesis was obtained from Air Force Systems Command's Foreign Technology Division; the rest was taken from aviation magazines and similar sources. Some information on the U. S. Air Force acquisition process was provided by organizations within the Aeronautical Systems Division of Air Force Systems Command.

An analysis of Soviet national objectives relevant to military power projection is necessary to understand Soviet intentions. An examination of national objectives should explain how and why requirements for new weapon systems are made. In response to national objectives, military strategies and tactics are created, which in turn necessitate specific capabilities. While aircraft engines are not considered weapon systems, they are the most critical subsystem on weapon systems like modern fighter aircraft. The complexity of modern aircraft engines and the extreme expense of developing them require a thorough, systematic approach to acquiring them. A study of the Soviet engine acquisition process and the organizational structure involved provides an understanding of the capability of a potential enemy to field a new airborne weapon system.

Because of the reliance on unclassified reports and secondary sources, some assumptions were made in the analysis of the Soviet system. The first assumption was that changes occur slowly in large bureaucracies such as the Soviet defense industrial ministries. The second assumption was that the Soviets have not deliberately given false information to Western aviation experts. A third assumption was that reporters in Western aviation magazines have made an attempt to verify through other sources information received. Although the author has attempted to find more than one source for significant points made within the thesis, there is no way to confirm independence of the sources.

An analysis of the Soviet aircraft engine acquisition system with respect to its strengths and weaknesses is made following the chapters which describe the Soviet acquisition process and organizations and which make comparisons with the U. S. Air Force engine acquisition system. Finally, some conclusions are drawn and recommendations for further research are made.

III. Soviet Military Doctrine

Introduction

Soviet national objectives have for seven decades been determined by the Communist Party of the Soviet Union (CPSU). Soviet military policy is defined by the Party as one means of achieving certain of those objectives. The Party's military policy is then written into a comprehensive and unified military doctrine applicable to the entire Soviet Armed Forces. From this doctrine, military strategies are formed. These strategies demand certain military capabilities, which are transformed into requirements for military weapon systems. This section of the thesis describes how Soviet national objectives precipitate requirements for new weapon system development, and attempts to focus on conventional force doctrine and development rather than strategic nuclear doctrine.

National Objectives

The Communist Party of the Soviet Union has the primary responsibility for the formulation of Soviet national objectives. These objectives are influenced by political, economic, social and geographic factors (60:30). The Soviet authors of Military Strategy describe the foreign policy objectives of the Communist Party of the Soviet Union as "the securing of peaceful conditions for the building of communism in the USSR and the development of a world socialist system" (49:xlv). They further state that the guiding principle of that foreign policy is the "struggle for peaceful coexistence of countries with different social structures; for general and complete disarmament, for banning the nuclear weapon, a struggle to exclude world war from the life of society" (49:xlv). Warner states "the most fundamental security objectives of the Soviet leaders are the defense of the communist regime and the territorial integrity of the USSR" (60:11).

Numerous military conflicts over what is now Soviet territory, by the Mongol hordes, by Napoleon's armies, by imperial and Nazi Germanies, and by others have created what some consider a Soviet paranoid obsession with defense of the homeland. Whether due to obsession or prudence, the might of the Soviet Armed Forces is considered the foundation for the Soviet Union's superpower status. As identified by the U. S. Air Force, the fundamental objectives of Soviet military power are to:

> - Defend the USSR as the socialist homeland and ensure the decisive and full defeat of any enemy who would dare attack the Soviet country.
> - Ensure favorable international conditions for the building of socialism and communism.
> - Ensure together with the other socialist countries the reliable defense and security of the socialist camp.
> - Provide support to national liberation movements. (13:96)

These objectives form the basis for the development of military doctrine, which defines the role of the Soviet Armed Forces in Soviet and world society.

Doctrine

Soviet military doctrine was defined by the late Defense Minister Marshal A. A. Grechko as "an officially accepted system of views in a given state and in its armed forces on the nature of war and methods of conducting it and on preparations of the country and army for war" (51:4). The Soviet Officer's Handbook states that:

> Present-day military doctrine is the political policy of the Party and the Soviet government in the military field. This is an expression of state military policy, a directive of political strategy-military strategy representing a true union of politics and science in the interests of defending the country and the whole socialist community against imperialist aggression...Soviet military doctrine is based on the calculation of the political, economic, scientific and technical and military factors and military scientific data. Its principal theses determine the main trend in military development, and establish common understanding of the nature of possible war and of the tasks involved in defending the state and preparing it to repel imperialist aggression. (51:5)

Soviet military doctrine is a system of official views and positions which establishes the direction of military development, the preparation of the nation and its armed forces for war, and the ways and means of conducting it (13:95).

Soviet military doctrine is developed and defined by the political leaders of the USSR in the Politburo of the Communist Party (60:50). With significant input from the Defense Council and from the Soviet military, the Politburo formulates military doctrine through an analysis of the likely nature of future conflict, the most likely enemy, the political, economic, and military means of waging war, and the means to prepare the nation for war. Defense policy alternatives are presented to the Politburo for final decision by the Ministry of Defense, and in particular, the General Staff (60:59).

Soviet theory has consistently emphasized that doctrine has both political and technical aspects, and that the political aspect is the more important of the two. The political element of doctrine, is created by the top members of the Communist Party. Colonel N. N. Azovtsev wrote that "the political side discloses the social and political essence of war, the character of political goals and strategic tasks of the state in war and its influence on military structuring" (51:258). One such political objective has been the victory of socialism over capitalism. The struggle for victory has been measured by the Soviets in terms of "correlation of forces," a concept the definition of which is much more broad than the West's "balance of power," which looks solely at military power. "Correlation of forces" takes into account political, economic and social factors in addition to military factors (11:2). In light of recent events in the Soviet Union and in Eastern Europe, this objective may now be defunct.

Colonel Azovtsev stated that the military-technical side of doctrine "points out the ways, means and methods of the fulfillment by the Armed Forces of the USSR of the military-political task placed before them" (51:258). The technical element of doctrine must be continuously revised in response to technological advancements achieved by either side. New military capabilities on one side may necessitate a response by the other in terms of developing a similar capability or a counter to that capability.

Former Defense Minister Marshal Malinovskiy wrote that the "best method of defense is to warn the enemy of our strength and readiness to smash him at his very first attempt to commit an act of aggression" (49:xli). All three editions of Military Strategy include a description of the Program of the CPSU which declares:

> The internal conditions of the Soviet Union do not require the existence of an army. However, as long as there remains a threat from the imperialist camp, and a complete disarmament has not been achieved, the CPSU deems it necessary to maintain the defensive power of the Soviet state and the combat readiness of its Armed Forces at a level which would guarantee the total destruction of any enemy who would dare to infringe upon the Soviet Union. (49:xlvi)

From the end of the Second World War until Stalin's death in 1953, Soviet military doctrine focused on the use of massive conventional forces. Several events caused a major change in thinking. In August 1949 the Soviets detonated their first atomic weapon. Four years later the first Soviet hydrogen bomb was tested. In 1957 the Soviet Union tested the world's first intercontinental ballistic missile. In December 1959 the Strategic Rocket Forces was formed and immediately became the preeminent service in the Soviet Armed Forces. One month later Nikita Khrushchev described a new military doctrine based on the premise that the next major war between major powers would be fought with massive nuclear strike weapons. Marshal Sokolovskiy echoed this doctrine of unlimited global thermonuclear war in his 1962 book Military Strategy. This doctrine led to an intense buildup of nuclear weapons in which the Soviet Union eventually surpassed the United States in numbers of warheads. This concentration on strategic nuclear weapons caused the Soviet Union's conventional weapons capabilities to fall behind those of the Western powers.

In the early 1970s, Soviet military doctrine was apparently changed to recognize that a limited nuclear war might be possible. In 1982, Marshal Nikolai Ogarkov wrote that "a revolution in military affairs, in the full meaning of the word, is taking place," based in part on qualitative improvements in conventional weapons (48:869). Ogarkov believed that wars could remain conventional because technological developments "will make it possible to conduct military operations with the use of conventional means of qualitatively new and incomparably more destructive forms than before..." (48:869).

In the 1970s the Soviets envisioned the possibility of winning a war in Europe through the use of conventional weapons before NATO's theater nuclear weapons could be employed. Such a conventional war would be won by massive combined-arms ground forces capable of high mobility and firepower, supported by deep air strikes into the enemy's rear. During the late 1970s and the 1980s, Soviet conventional forces were greatly enhanced by the additions of numerous new weapon systems with significantly improved combat capabilities.

Deterrence has served as the foundation for U. S. military doctrine for many years: the U. S. would inflict an unacceptable level of damage to the Soviet Union in retaliation for acts of war. In the arena of strategic nuclear weapons, this policy was known as "mutual assured destruction." This doctrine is seen as insufficient for Soviet needs, as deterrence through the threat of retaliation may fail. Currie states that since the very survival of the Soviet system may be at stake in the next major war, the Soviet Armed Forces must be capable of winning, and therefore Soviet military power is based upon a massive counterforce capability (i.e., against opposing military forces, as opposed to countervalue targets like population centers) (11:5).

To ensure military victory, the Soviet Armed Forces must be capable of destroying the enemy's military forces with counterforce strikes in any type of conflict, while simultaneously limiting the damage to the Soviet homeland. Soviet military doctrine emphasizes offensive operations involving superior forces massed at the point of attack. The ground forces would be protected and supported by air operations to gain air superiority and to strike deep into enemy territory. These missions for the Soviet Air Forces create requirements for certain capabilities which must be satisfied by the defense industrial ministries of the Soviet government.

Strategy

Marshal Sokolovskiy defined military strategy as a "system of scientific knowledge dealing with the laws of war as an armed conflict in the name of definite class interests" (49:11). Soviet military strategy is developed according to the "known laws of war" proposed by Marxist-Leninist theory. In the preparation of Soviet military strategy, the "postures of military doctrine, the experiences of past wars, military and political conditions, the economic and moral possibilities of the country, new means of battle, and the views of the probable enemy" are considered (49:1). Sokolovskiy wrote that "military strategy cannot be developed without taking into account economical, political and scientific and technical factors" (49:8). Marshal Grechko stated that strategy

> encompasses questions of the theory and practice of preparing the Armed Forces for war, of planning and waging war, of using Services of the Armed Forces and directing them. Strategy is based on doctrine and relies on a country's economic capabilities. At the same time, it stems directly from a state's policy and is subordinate to it. (51:7)

The Soviet Officer's Handbook further explains that "Strategy implements doctrine directly, and is its instrument in the elaboration of war plans and the preparation of the country for war...War...is governed by strategy, not doctrine" (51:8).

Marshal Sokolovskiy and his coauthors of the second edition of Military Strategy state that military strategy "investigates the ways and means of armed conflict in the interests of state policy, which is formulated by the ruling class in a given country" (49:xlii).

Soviet writings emphasize that the development of strategy is dependent upon politics. Sokolovskiy wrote that Lenin declared the conduct of war was influenced by political aims, which determined the just or unjust nature of war. "Politics considers the requirements and reasons of strategy, as well as the potentialities of the state, seeking to make the aims commensurate with the forces and means available" (49:18). Since military strategy is influenced by the current general line of state policy, which has consistently supported the building of communist society, "Soviet military strategy directed by such a clear and noble idea acquires the necessary direction and consistency" (49:17).

Because strategy determines the general nature of future military action (the enemy, the overall goals, force level requirements, and general military operational plans), tactics are considered subordinate to strategy. Tactics have similar meanings in both the Soviet and US armed forces:

> Tactics is that part of military art which is directly concerned with fundamentals of preparing for, and conducting, combat operations by subunits, units, and formations of all the branches and Services of the Armed Forces on land, in the air, and at sea. (51:9)

Tactics relates to the employment of existing forces; it is strategy which determines the need for weapon system capabilities.

Requirements

New requirements for weapon systems are generated in response to capabilities demanded by revision of military strategy. The nature of the mission for each particular system determines the capabilities required. These capabilities are translated into specific requirements for the weapon system, which in turn drive the characteristics of its components.

For example, when the U. S. began efforts on the XB-70 supersonic high altitude bomber, a new threat to the Soviet homeland was perceived. Soviet national objectives include defending Soviet territory from attack. Doctrine may state that the Soviet Armed Forces be structured so that one branch has the sole mission of defending the homeland from attack. To counter the bomber threat, the Air Defense Forces strategy is to employ interceptor aircraft to meet and defeat enemy bombers before they can enter Soviet territory. For this mission, an interceptor requires a high fuel fraction and engines with high thrust. Since no current aircraft was capable of meeting the specific requirements, the Mikoyan MiG-25 FOXBAT was designed specifically to counter the B-70, which was canceled before production (10:17). In response to requirements for powerful new engines, the Tumanskiy Engine Design Bureau developed the R-266 afterburning turbojet engines for the MiG-25 which were capable of propelling it to nearly Mach 3 (30:845).

Effects of Perestroika

Soviet defense policy has historically been formulated largely by the Soviet General Staff. Although the Politburo retains authority for final policy decisions on defense concerns including the defense budget, the composition of the Soviet armed forces, and the content of Soviet military doctrine, the Soviet General Staff has provided input to these decisions in the form of policy options (5:9). The procedures for defense policy formulation are apparently undergoing changes under President Gorbachev. He has increased civilian control over the formulation of defense policy, and has taken a strong hand in it himself. While addressing the 27th Party Congress in January 1986, Gorbachev stated that "our country stands for ... restricting military potentials within the bounds of reasonable sufficiency. But the nature and limits of these bounds continue to be limited by the positions and actions of the United States and its bloc partners." Gorbachev failed to define "reasonable sufficiency," and appears to be leaving the formulation of a definition to military and civilian experts. The Soviets appear to be still exploring this concept rather than refining it.

In order to obtain new approaches to national security issues and to reestablish Party control over the military, Gorbachev has encouraged civilian defense analysts to provide input to the process. The military's former monopoly on defense information has been degraded under Gorbachev's policy of glasnost, or openness, allowing civilian analysts more influence in defense policy-making. These new participants in the creation of Soviet defense policy include key personnel from research institutes of the Soviet Academy of Sciences such as the Institute of the U.S.A. and Canada, the Institute of World Economy and International Relations, and the newly created Institute of Western Europe (5:11). Since Gorbachev has declined to make detailed defense policy statements, military experts and civilian analysts are attempting to determine what force levels, structures, and capabilities constitute "reasonable sufficiency," and whether changes in military strategy are required (5:14).

As might be expected, there appears to be much disagreement between the military establishment and civilian analysts over the definition of sufficiency. The civilians believe that military parity should be evaluated in terms of qualitative, not quantitative, criteria, and that responses to the enemy's moves should be asymmetrical rather than symmetrical. They argue that "Soviet security does not depend on a symmetrical response to every move by the enemy," and that matching the U. S. weapon system for weapons system serves only to bankrupt the economy and forces the Soviet Union to compete in the enemy's game under the enemy's rules (5:19). The civilian analysts advocate a thorough and realistic evaluation of the enemy's intentions be included in the formulation of defense policy.

The Soviet military leaders appear to support traditional views of strategic parity as a stabilizing factor and favor symmetrical responses to aggressive enemy actions. The Soviet military establishment believes that its force posture should be directly linked to the U. S. force posture, so that their interpretation of the limits of reasonable sufficiency is defined by the U. S. force structure (5:22). The military professionals do not support the idea of nonoffensive defense proposed by civilian analysts.

In summary, the leaders of the Communist Party of the Soviet Union, with input from the Soviet Armed Forces, develop a unified military doctrine in order to plan for the accomplishment of certain national objectives. This doctrine identifies the nature of future war, the most likely enemy, general plans for the employment of forces, and the preparation of the country for war. In line with this doctrine, the Soviet military creates strategies for the employment of the total Armed Forces, and tactics for the employment of small units. These strategies and tactics demand specific military capabilities which are transformed into requirements for weapon systems, the first step of the weapon acquisition process. Although the participants in the development of doctrine are changing, the process itself is believed to remain the same.

IV. The Soviet Engine Acquisition Process

Introduction

The acquisition of weapon systems in the Soviet Union takes place entirely within the government of the Soviet Union: both the consumers and manufacturers of aerospace systems are government organizations. The resources and facilities necessary for the creation of aerospace systems are owned and operated by the Soviet government. No private aerospace industry exists as in the United States. This section of the thesis describes the development and acquisition of aircraft engines in the Soviet Union, from requirements generation through series production, and discusses the roles of the national-level policy-making and oversight organizations controlling the process. The following section provides details on the specific Soviet organizations involved in the development and acquisition of aircraft engines. While there is some necessary redundancy when describing separately a process and the participants, an attempt has been made to avoid excessive repetition.

Party and Government Control

The centrally planned Soviet economy has been controlled by the Communist Party of the Soviet Union (CPSU) throughout twelve five-year plans. The Communist Party pervades all aspects of life of Soviet life. However, the CPSU's total domination of the Soviet government is being challenged today. At the five-year meetings of the Communist Party Congress, a Central Committee is elected. The Central Committee Politburo, the CPSU's highest policy-making body currently headed by CPSU General Secretary Mikhail Sergeivich Gorbachev, is composed of twenty-four full (voting) members who determine the party's, and thus the government's, objectives and methods of achieving goals, and of special importance to this thesis, deciding and implementing military doctrine and weapon system acquisition (62;16:16). Additionally, there are eight candidate (non-voting members). The current Minister of Defense, Dmitri Yazov, is a candidate member (62). It is significant that Yazov has not been made a voting member; therefore, the military's influence in running Soviet national affairs is consequently diminished.

The CPSU Central Committee's Department for Defense Industries, headed by Secretary for Defense Industrv O. D. Baklonov, monitors "all matters relating to research, development, and production of military-related hardware" (62;47:3).

At the top of the legislative branch of the Soviet government is the Congress of People's Deputies, recently created above the Supreme Soviet, the Presidium of which was once the highest government entity (62). President Gorbachev now heads the newly established executive branch of government, and has veto powers over legislation enacted by the Supreme Soviet.

The Defense Council, which has been compared to the American government's National Security Council, comprises the top members of the Party, government, and military. It implements "supreme organisational, executive and control functions on specific issues of the country's defence capability and security," and oversees "strategic, doctrinal budgetary and personnel issues" (53:1382). Recent Soviet political changes have affected the Defense Council, whose non-military membership has been increased, diluting the military's control over defense matters (29:129).

The Council of Ministers, led by Prime Minister Nikolai Ryzhkov, is considered to be the working level of Soviet government. It is composed of nearly 100 members, including the eight defense-industrial ministers and one committee secretary, as well as the ministers of all the civilian industries (62;16:16). In 1985, the Bureau for Machine Building, headed by former Aviation Industry Minister Ivan Silayev, was created under the Council of Ministers to oversee all activities of the machine building industrial ministries (4:22). The Military-Industrial Commission (VPK), headed by I. S. Belousov, has oversight authority over all defense production matters. The VPK is responsible for coordination between the military customer and the defense industrial ministries (47:4). Its membership comprises the defense-industrial ministers, ministers of supporting civil industries, and representatives of the State Planning Committee (GosPlan), the Ministry of Defense

(MO), the CPSU Central Committee Secretariat, and possibly the Ministry of Finance and the State Committee for Science and Technology (GKNT) (62). The GKNT was established in 1965 to "plan, oversee, and regulate scientific research and development, and to recommend the introduction of technological innovations throughout the economy (2:8).

Within the Ministry of Defense (MO), the Deputy Minister of Defense for Armaments, currently Vitaliy Shabanov, has the responsibility for coordinating military doctrine and weapons technology, and for coordinating the planning, development, testing, and production of weapon systems for the Soviet military (10:16). Figure 1 illustrates the structure of the Soviet defense industry.

In order to manage such a large economy, Soviet central planners of the State Planning Committee (GosPlan), among others, rely on five-year planning and budgeting cycles. GosPlan is responsible for "allocating and monitoring the use of resources approved by the Council of Ministers and the Politburo" (47:4). The Soviet Union is currently nearing the end of the Twelfth Five-Year Plan; the Thirteenth FYP will begin in 1991. Financial and schedule constraints within each plan are rigidly followed in order to successfully meet goals for industrial output (52:15-16). It is in this environment that the acquisition of major programs, both military and civilian, takes place.

In order to standardize the acquisition process, the Unified System of Design Documentation (YeSKD) was

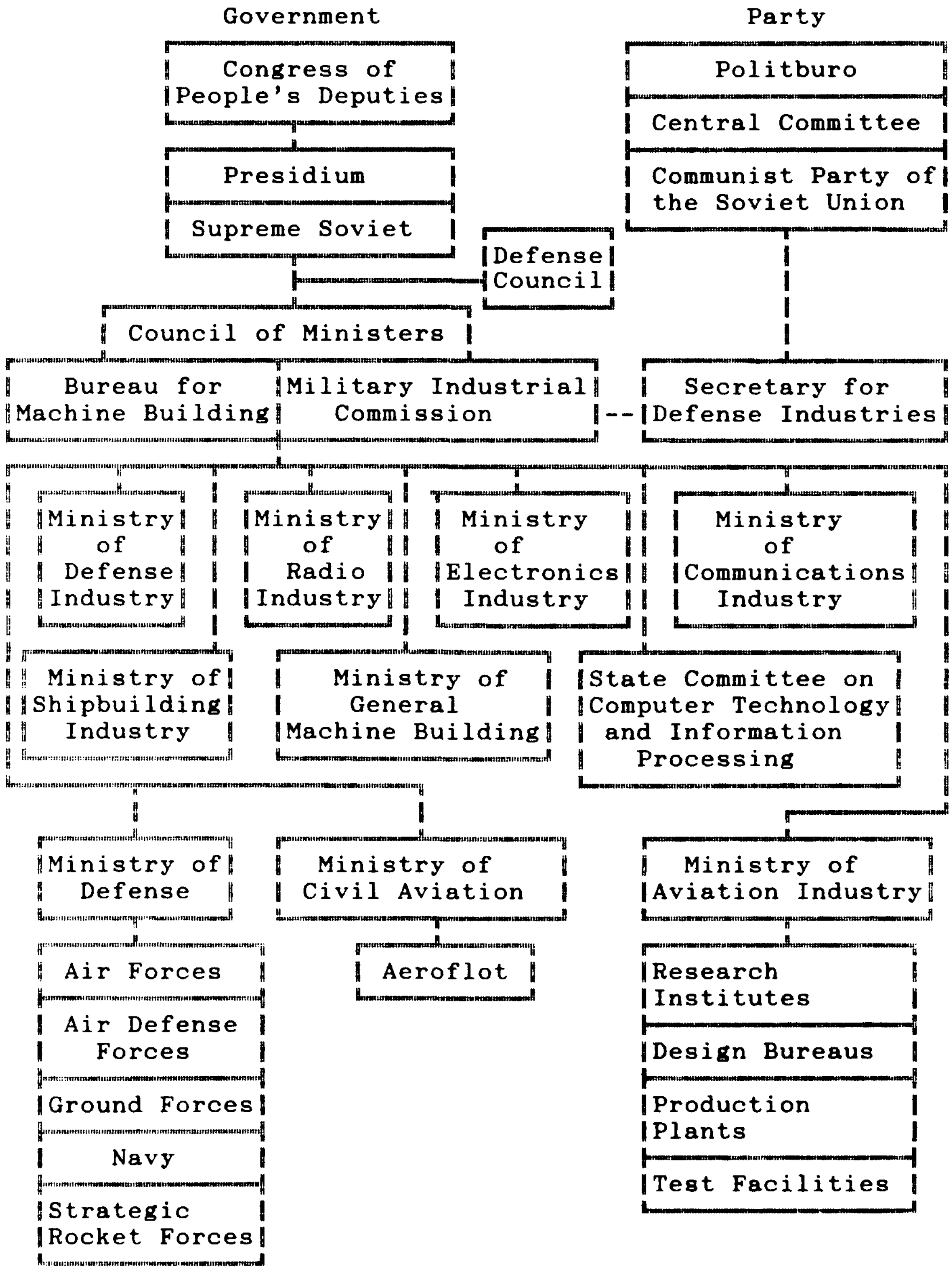


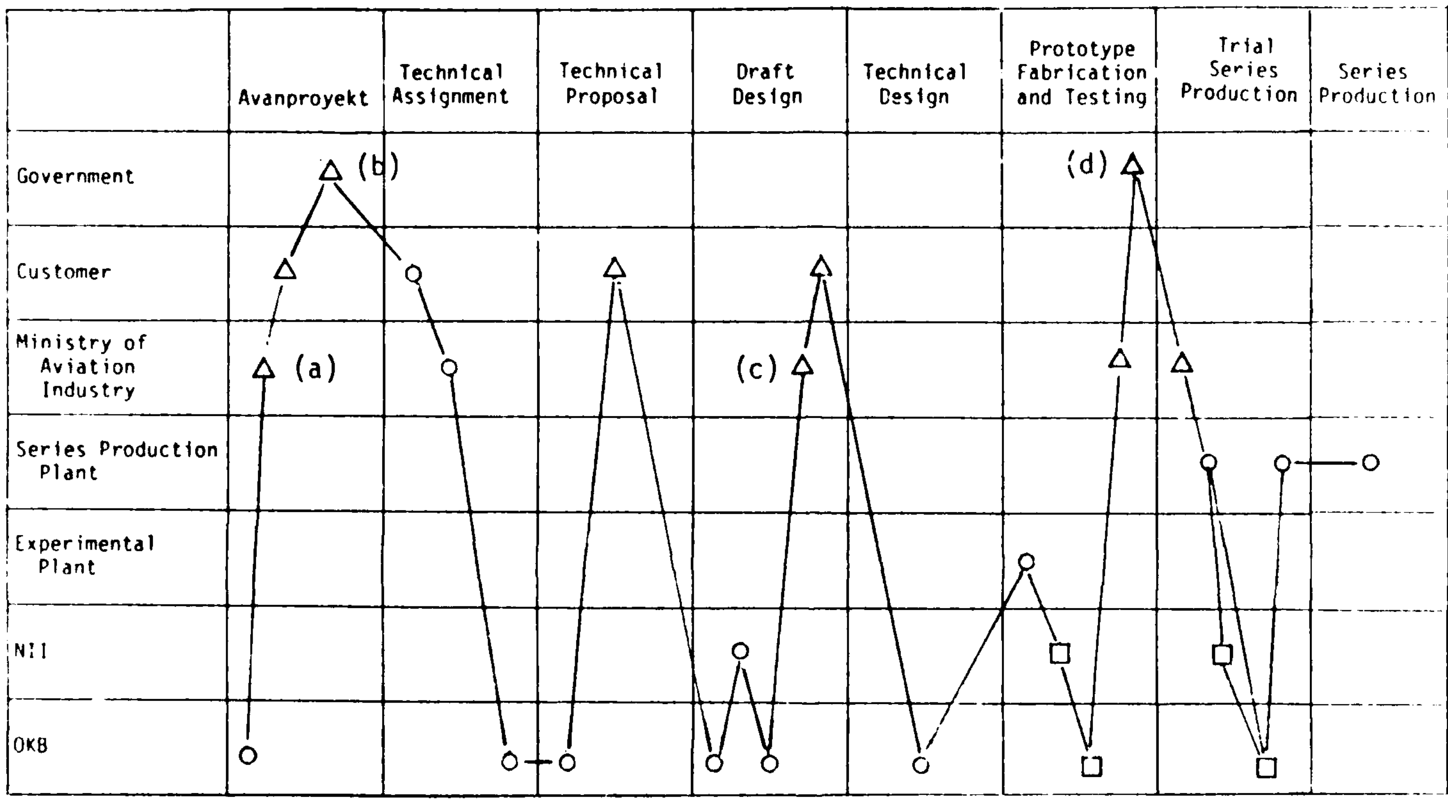
Figure 1. Organization of the Soviet Defense Industry

established by law in 1971 (46:1). As a state standard (Gost 2.103-68) the YeSKD provides a common procedure for acquisition requiring common design documentation and terminology for every industry, both military and civilian, with some individual variations allowed. Other inter-industry state standards include the Unified System of Technological Preparation for Production (YeSTPP) and the Unified System of Technological Documentation (YeSTD) (46:1).

The Soviet Engine Acquisition Process

The Soviet aircraft engine acquisition process has its origin in the establishment of national objectives by the CPSU leadership. From these national objectives, military doctrine is written to define potential military conflict and methods to prepare the nation for such conflict. Preparation of military strategies ensues, in which specific military capabilities are defined as necessary for the achievement of military objectives. The transformation of national objectives into specific requirements for new engines was described in the previous chapter.

Figure 2 illustrates the steps of the Soviet weapon system acquisition process. The engine acquisition process itself begins with the generation of specific requirements following identification of an operational need by a customer, defined for the purposes of this thesis as either the Ministry of Defense (MO) or the Ministry of Civil



(a) Review by S & T Council
(b) Decree to start development issued
(c) Approval by specially formed commission
(d) State Acceptance Commission

○ - Basic activity
△ - Review/Approval
□ - Testing

Figure 2. The Soviet Weapon System Acquisition Process

Aviation (MGA), both part of the Council of Ministers. More specifically, the customers for new aircraft engines are the Soviet Air Forces of the MO and MGA's Aeroflot (the national airline). This requirement for a new engine will be made by the customer (most likely as part of a requirement for a new aircraft system) in a document called a Technical Requirement (TT) for a civilian system or a Tactical Technical Requirement (TTT) for a military system. The TT or TTT defines the customer's specifications for size, performance, and costs of manufacturing and operation (57:22). After validation of the requirement by the approving authority, the requirement is forwarded to a scientific and technical commission which examines the feasibility of the project and develops further specifications for the new design. Competing design bureaus are tasked with preparing an engineering proposal (57:23).

Research institutes of the Soviet Academy of Sciences, and to lesser degrees, of the defense industrial ministries, continuously perform basic scientific research work (NIR) in order to expand the Soviet technology base. The primary research facilities within the Ministry of Aviation Industry are the Central Aerohydrodynamics Institute, which performs research in the aerodynamics of aerospace vehicle design, and the Central Institute of Aviation Motor Building, which conducts research in propulsion technology. Other MAP research institutes are, among others, the Flight Research Institute and the All-Union Institute for Aircraft

Materials. In addition to the research institutes of MAP there are other research organizations in the other defense industrial ministries, in the Ministry of Defense, in the civilian ministries, and those of the Soviet Academy of Sciences and the State Committee for Public Education, all of which contribute to the nation's technology base. These institutes prepare design handbooks which "closely control the choice of technologies, components, and manufacturing techniques" available to the designers in order to minimize the degree of risk involved in the project (4:14,7:128). Although the technology base is surveyed during requirements generation, much more thorough analysis is usually necessary for determination of project feasibility. For this reason, goal-oriented scientific research work is conducted in order to evaluate alternatives and provide technical options prior to tasking of design bureaus.

Goal-oriented NIR begins when a Technical Assignment (TZ) specifying research objectives is issued to research institutes, which analyze the customer's requirements and the existing technology base, and forecast the development of domestic and foreign technology (57:25). Next, in the second stage of goal-oriented NIR, the research direction is selected and formalized in the Technical Proposal which documents the means for conducting the research. The third stage involves theoretical and experimental research necessary for proving the technology is feasible. Upon completion of this stage a feasibility study is made on the effectiveness of using the research results. In the final stage of goal-oriented NIR, a report presenting the research results and possible applications for the research is made to the research institute's scientific and technical council. If approved by the council, the results are made available to various interested organizations (57:27). Design bureaus may then make use of this "proven" technology.

Experimental design work (opytno-konstruktorskaya rabota, or OKR) is that work performed by the experimental design bureau (OKB) between project approval by the government and series production, involving the "incorporation of existing technology into finished and tested technical design/production drawings and specifications" for the production of weapon systems (47:5). Upon receipt of the requirement, the design bureau prepares conceptual designs and forwards an engineering proposal through the Ministry of Aviation Industry for customer and government approval. After evaluation of the proposal, the Military Industrial Commission (VPK) may authorize the design and development of the new system through prototype construction. Its legally binding decision sets overall project goals, names the lead organization and participating organizations (primary and support design bureaus, production plants), sets project timetables, and allocates funding for the entire design/development phase (4:14, 57:30).

Upon approval of the engineering proposal, the Technical Assignment (TZ) is issued through MAP to the participating design bureaus and production plants. The TZ defines the basic parameters of the new article, estimates its cost, and establishes the stages of work to be performed. Acceptance of the TZ is the initial stage of YeSKD (46:3,5).

Design Documentation is begun with the Technical Proposal (TP) stage. In writing the Technical Proposal, the developing design bureau refines estimates made in the TZ, identifies additional requirements, examines various design options and selects the optimal, and sub-tasks work to supporting component design bureaus. If the customer approves the Technical Proposal submitted by the lead design bureau, the Draft Design stage is begun (46:12).

During Draft Design, the design bureau selects major design principles, and fabricates and tests models. The design bureau may submit the draft design to scientific research institutes for evaluation during this stage. Once the Draft Design receives MAP and customer approval, the Technical Design is begun (46:12).

In Technical Design, the design bureau selects the final design for the article, analyzes the design for standardization and producibility, and develops design documentation for the engine and its components. After completion of this stage, the Working Documentation for Prototype phase is begun. In this phase, as the name suggests, working documentation for the prototype engine is developed. The first working prototype, called the pilot model, of the engine is then manufactured and tested in the experimental production plant collocated with the design bureau, and further design refinements are made (46:6,12; 11:18). The Central Institute of Aviation Motor Building possesses altitude simulation test facilities which may be used by engine designers to determine engine performance under simulated flight conditions. Further testing may be conducted in a flying testbed operated by the Flight Research Institute. A prototype engine is installed in place of a regular engine, and tests under actual flight conditions are performed. These tests are monitored by the customer and the Ministry of Aviation Industry as part of state acceptance testing.

Upon successful completion of state acceptance testing of the "pilot lot" of additional engine prototypes, a joint decision of the Central Committee, Council of Ministers, and the customer approves the article for series production. The primary responsibility for the engine then shifts from the design bureau to the series production plant where it will be produced in quantities as required by the customer (46:12,15; 10:18). The design bureau is then responsible for technical assistance to the series production plants. At first, a small number of articles, called the trial production lot, are manufactured by the production plant and tested to ensure that the lot meets the same specifications as the pilot lot manufactured at the experimental plant attached to the design bureau (47:7). Military representatives are assigned to the production plants to perform quality control and to ensure that they (the customer) are receiving what was ordered (16:16). The Soviet system has historically had great difficulty in making the transition from development to production (62).

Soviet Weapon System Design Philosophy

The Soviet weapon system design philosophy has been shaped by Soviet political, economic, and military history. Dunlavey writes that the Soviet weapons industry was constructed "to complement their economic and industrial realities" (18:3). He explains that during the 1950s, the Soviet Union had

> "a large and unskilled labor force, an industrial base of general purpose tools and equipment, and the experiences of World War II - a war of attrition in which quantity counted for more than quality". (18:3)

Many of the Soviet Union's top weapons designers began their careers during this period. In the Soviet system, engineers and technicians tend to remain in the same organization over most of their careers; those at the top of an organization have worked their ways up through the ranks. Many of these chief designers headed their organizations for decades. This type of employment and leadership stability is not typically found in the United States.

Shymansky states that "the meeting of development schedule deadlines is considered imperative in Soviet thinking" (47:8). In the Soviet system of central planning, where each development phase is performed by a different organization, each organization must depend upon other organizations meeting their individual schedules. The Soviet acquisition process encompasses an early design freeze to prevent schedule slippage. Use of advanced technology not yet proven on operational systems increases the risk of missing schedule deadlines. Designers are therefore more likely to use whenever possible proven, off-the-shelf components "that can be counted on to perform to acceptable (though perhaps not optimal) standards (2:11). Many weapon systems thus have similar components.

This situation has resulted in the development of a very conservative design philosophy of evolutionary improvements with a tendency to avoid technological risk. Alexander declares that "Designers, customers, and producers employ strategies that ensure progress and avoid radical solutions ..." the failure of which might endanger meeting schedules (4:14). Mikhail Mil, a helicopter designer, reportedly told his subordinates to "make it simple, make it rugged, make it reliable, and make it work" (18:4; 31:706). Soviet weapon systems in general are characterized by a "good enough" approach, in which materials and workmanship are the minimum necessary for mission accomplishment. Producibility is a prime design requirement (49:8).

A particularly good example of the design philosophy of simple but adequate systems is the Tumanskiy R11-300 turbojet engine used in many MiG-21 fighter aircraft. This engine comprises approximately 2,500 parts, and must be overhauled after 300 hours of operation. Tolerances and finishes are crude except where absolutely necessary. The Soviet engine could have been manufactured with technology available in the United States in the 1930s. In contrast, the roughly comparable J-79 engine for the F-4 fighter contained nearly 22,500 parts, and did not require its first overhaul until 1,500 hours of operation. The American design utilized extensive redundancy and control mechanisms. (10:25;24:20) It was estimated that the Soviet production cost was one-third of the American cost, and life-cycle cost estimates "indicated a Russian advantage of over 50 percent" (3:8).

Another aspect of Soviet weapon system design is the use of Western technology. In response to threatening Western technological advances in the 1960s and 1970s, the Soviets mounted a "massive, well-planned and well-coordinated ... program to acquire Western technology..." (18:5). According to Buffalo and Rogers, the incorporation of proven Western technology into Soviet weapon systems saves millions of rubles of research and development costs, as well as many years of development lead time (6:20).

Effects of Perestroika

President Gorbachev's perestroika, or restructuring, initiatives, enacted by the 27th Party Congress in March 1986, are having an effect upon the organizations of the

Soviet Ministry of Aviation Industry. The role of the CPSU is being decresed in favor of the new executive branch. Methods of funding are being altered; past management practices are being attacked as inefficient. Under the policy of konversiya, the defense industrial ministries are being ordered to produce more civilian consumer goods of higher quality than was previously available. Despite the many changes to the daily operations of the Soviet defense industry forced by perestroika, the basic acquisition process as defined by Soviet state standards does not appear to have been greatly affected to this date.

The defense industrial ministries, long shielded by high priorities from the economic hardships endured by other ministries, are now feeling the effects of changes enacted as part of Gorbachev's restructuring reforms. The Soviet Union's central planners are forcing the defense industrial ministries to help rebuild the civilian sector of the economy. Defense industry managers are being transferred to civilian jobs in order to provide that sector with expertise on increasing productivity and efficiency. To oversee all ministerial machine building affairs, the Council of Ministers established the Bureau of Machine Building in 1985. Aviation Minister Ivan Silayev was promoted to head the new bureau; two of his deputies were also moved: one to the bureau under Silayev, one as deputy chairman of the State Planning Commission (4:22). Many articles have appeared in the Soviet press urging the civilian industries to adopt the management practices and competition found in the defense industrial ministries.

The defense industrial ministries are simultaneously facing significantly reduced funding and the principles of "economic accountability" and "self-financing." One source states the Soviet aviation industry faces "20% cuts in funding from the military next year and yet deeper cuts later on" (37:28). Another says the Ministry of Aviation Industry was reportedly facing a 14.2 percent reduction in military spending in 1990 "without any corresponding transfer of funds to the civil sector" (46:26). As rubles become less available to the defense industrial ministries, new ways are being sought to fund their operations. TsIAM Director Ogorodnikov stated:

> Up to now we have lived mainly on the money given to us by the Ministry of Aviation Industry. We are now changing to earn our own money. NASA is financed by the state and by companies using its services, and we hope to do the same thing. (40:43)

Ministry of Aviation Industry research institutes like TsAGI and TsIAM are searching for new customers and research partners in domestic civil ministries and in foreign industry, as evidenced by the Soviet Aeroengine '90 Exhibition. Both organizations are offering their services to Western aerospace companies to compensate for decreasing ministry funding (TsAGI's funding reportedly declined 10 percent from 1989 to 1990) (39:29). Prior to perestroika, TsIAM's funding originated entirely with the ministry, and now nearly 40 percent comes from "industry" (39:29). MAP's chief scientist, Aleksander Batkov, opposes requiring research institutes to be self-financing, and states that this requirement will decrease research efforts and will slow the growth of the overall technology base at a time when MAP wants to compete in the international aviation market (46:26; 39:28).

Progress Engine Design Bureau's General Director Fyodor Muravchenko related that perestroika was forcing the design bureau to find ways to cut costs.

> For example, previously we weren't forced to think too much about defect-related engine removals because we knew it would be compensated by the ministry. But now these costs are taken from our contract funds, so we think more about cutting costs. In the past, I could be reprimanded, but now the whole collective, our personnel and staff, will lose money. (39:48)

Muravchenko also stated that the financing of new projects has been affected by perestroika. "In the past, a project was funded if the idea was accepted, but now the funding may be delayed" (39:48). Boguslayev said his production association was now making its own contracts, a function performed previously by "others" (33:50). Additionally, the Soviet aerospace industry is seeking new markets for its products. A new priority to "outsell Western manufacturers in the emerging Far Eastern airliner market" has been mentioned (37:28). Increased cooperative ventures with Western aerospace firms have been undertaken (43:25; 40:43).

Deputy Chairman S. Yefimenko of the USSR Sate Committee for Science and Technology (GKNT) described in a 1987 newspaper article changes in the system of R&D management that were to have been in place by 1989. Research results would be considered a "commodity;" all research work for clients would be performed on the basis of contracts, and all contract work must be paid for (28:2). The new system provides incentives for quality work, as contracts will be awarded on a competitive basis. Whereas in 1987 the state appropriated more than 30 billion rubles for research institutes and design bureaus, in the future their income would depend directly upon their research results and the introduction of their results into the economy (28:2). The state would continue to support "institutes engaged in basic research and others whose developments have no immediate industrial applications" (28:2).

Former Moscow Party boss Lev Zaikov stated that "in 1989, 43 percent of defense sector production was earmarked for the civilian economy," a figure projected to reach 60 percent by 1995 (53:1382). In addition to the increased production of consumer goods required under konversiya, production of military items is being scaled down in some plants. Zaporozhye Engine Production Association Director Boguslayev stated that "27-30 percent of production in 1989 will be for the military, down from about 35%" in the previous year (33:50).

The restructuring reforms have apparently proceeded at an unsatisfactory rate. At a Central Committee conference in July 1987, Gorbachev criticized the lack of progress by the machine building ministries. He stated that "accelerated development of machine building holds the key to quickly modernizing the country's industrial base and to achieving high, stable rates of economic growth" (23:1). Machine building ministries reportedly were not fulfilling the state's June 1986 comprehensive plan for modernization of facilities and the production of new consumer goods.

Summary

This section of the thesis described the Soviet acquisition process for major development programs like aircraft engines. As with all major Soviet weapon system development programs, aircraft engine development is schedule-driven and centrally managed by both party and government organizations. The Soviet engine acquisition process follows specific stages mandated by law and involves three main types of functionally separate organizations: research institutes, design bureaus, and production plants. Each phase of the acquisition of new aircraft engines is carefully monitored by the customer and by numerous government and party organizations with oversight responsibilities. Although the engine acquisition process itself has been relatively unchanged by perestroika at this writing, the daily operations of the defense industrial ministries have been unquestionably affected.

V. The Soviet Aircraft Engine Industry

Introduction

Whereas the previous section described the overall Soviet engine acquisition process and the role of national policy-making and oversight organizations, this section of the thesis focuses on the organizations in the Soviet Union's Ministry of Aviation Industry, which is responsible for the research, design, development, test, and production of air-breathing engines for military and civilian aircraft. The role of each organization in Soviet engine development and acquisition is examined, and each organization's design specialty is discussed. Some attention is given to the effects of the current restructuring efforts on each type of organization.

Organization of the Soviet Defense Industry

Unlike the United States, no private aerospace industry exists in the Union of Soviet Socialist Republics (USSR). All military-related systems, subsystems, and components are developed in the eight defense-industrial ministries and one state committee directly subordinate to the USSR Council of Ministers, which is in turn subordinate to the Supreme Soviet, headed by President Mikhail Gorbachev. The Council of Ministers is currently headed by Prime Minister Nikolai Ryzhkov. The Communist Party of the Soviet Union (CPSU) has historically controlled all levels of the Soviet government, as CPSU General Secretary heads the Supreme Soviet and the newly formed Congress of People's Deputies (62). Oversight of the planning and operations of the defense industrial ministries is performed by the Military Industrial Commission (VPK) (led by I. S. Belousov and responsible for coordination between the Ministry of Defense and the defense industrial ministries), and by the CPSU Politburo's Secretary for Defense Industries (currently O. D. Baklanov) (62). The Deputy Minister of Defense for Armaments, Vitaliy Shabanov, coordinates the planning, development, production, testing, supply, storage and repair" of armaments and support equipment (10:16). In 1985, Aviation Industry Minister Ivan Silayev was promoted to head the new Council of Ministers' Bureau for Machine Building, believed to have oversight responsibilities for both civilian and defense industrial ministries (4:22).

The defense industrial ministries have historically enjoyed the highest priorities for resources in order to expedite the research, design, development and production of specific articles of potential military value (2:3; 10:12). At least prior to recently announced cuts, the Soviet defense industry was "the fastest growing sector of the Soviet economy under Gorbachev" (14:34). These organizations have no counterpart in the United States, even when one considers the ill-defined "military-industrial complex." The defense-industrial ministries are supported to varying degrees by other civilian industrial ministries, and by the research institutes of the Soviet Academy of Sciences and of the State Committee for Public Education (GKNO). The main consumers of aerospace systems are the Ministry of Defense (the Soviet military, which comprises the Air Forces, Strategic Rocket Forces, Ground Forces, Navy, and Troops of Air Defense) and the Ministry of Civil Aviation (containing Aeroflot, the Soviet national airline).

The Ministry of Aviation Industry

The research, design, development, test, and production of Soviet aircraft, aircraft engines and components, and aerodynamic missiles is the responsibility of the Ministry of Aviation Industry (MAP), one of the eight (formerly nine) Soviet defense-industrial ministries (10:viii; 50:5). The Ministry of Aviation Industry is a large government organization comprising a number of scientific research institutes (NIIs), experimental design bureaus (OKBs), test centers, and series production plants, each of which play different and critical roles in the development of new aerospace systems (2:4-5; 40:13), as described in the previous section. The structure of MAP is illustrated in Figure 3.

The Commissariat for the Aviation Industry was created in 1939 in response to a perceived need for centralized management authority over the numerous independent organizations which had separated from the Central Aerohydrodynamic Institute (TsAGI) since its foundation in 1918 (57:15). The Commissariat was renamed the Ministry of

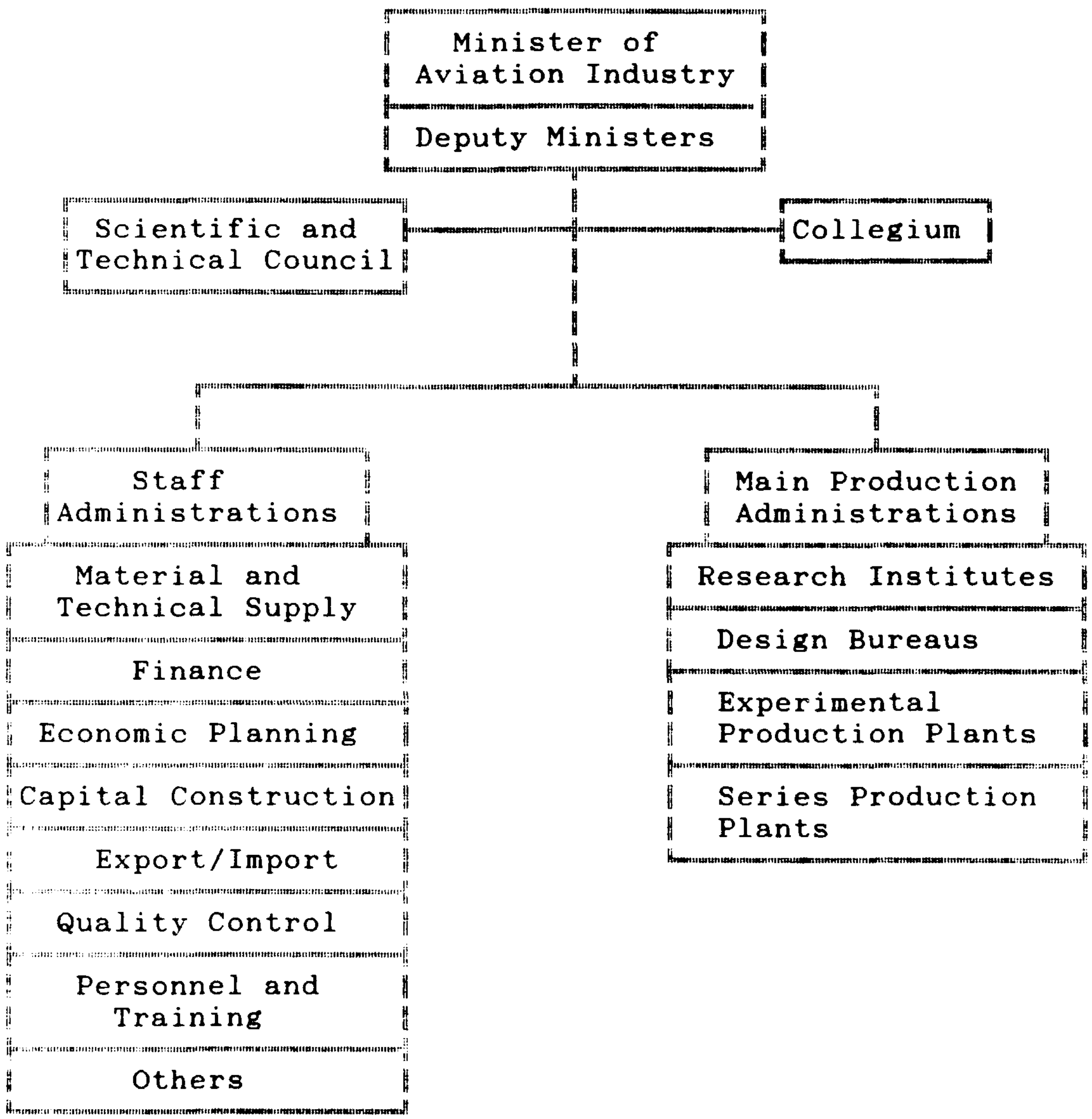


Figure 3. Organization of the Ministry of Aviation Industry (57:16)

Aviation Industry in 1946, but its basic structure is believed to have remained the same (57:16). The Minister of the Aviation Industry, currently Apollon S. Systsov, is an influential member of the Council of Ministers of the Soviet government who is personally responsible for the development of new aerospace systems. The minister exercises considerable power in obtaining funds for and controlling the numerous and expensive technological developments within MAP. The Ministry's Scientific and Technical Council, an advisory group of scientists, engineers, and technical specialists, assists the minister with technical problems. The Collegium of the Ministry of Aviation Industry, chaired by the minister and composed of deputy ministers like Viktor Chuyko, advises the minister on resource and program management problems. Functional staff divisions like Material and Technical Supply, Finance, Accounting, Economic Planning, Capital Construction, Quality Control, Export/Import, Personnel and Training, and others exist to support the minister and the main production administrations which make up the bulk of MAP (57:16).

The main production administrations comprise all the research institutes, design bureaus and production plants responsible for the creation of new and modified aerospace systems (aircraft and aerodynamic missiles) and components. Each of the research, design, and production organizations is independent of the others but subordinate to a main production administration of MAP.

Production associations were formed in order to alleviate the difficulties associated with having research, design, and production performed by separate entities. The first production associations (POs) in the 1960s grouped production plants with similar responsibilities. In the 1970s, scientific production associations (NPOs) were formed to combine research and design organizations with production organizations for special large projects (such as the Soviet space shuttle). To date it appears that no agreements to form NPOs between aircraft or engine designers and associated production plants have been formalized.

The Ministry of Aviation Industry has maintained a high rate of productivity despite President Gorbachev's restructuring program and its emphasis on civilian consumer goods. To illustrate this productivity, it is estimated that an average total of 47 bombers, 680 fighters, and 450 military helicopters were produced each year between 1986 and 1988 in the Soviet Union (14:34). Simultaneously, numerous civilian transport aircraft and all the necessary engines, components and spares for the military and civilian aircraft were produced. In addition to those systems in series production, many new aerospace systems are under development in the design bureaus of the Ministry of Aviation Industry. In conformance with the Unified System of Design Documentation (YeSKD), the Soviet national law governing the acquisition of weapon systems as described in the previous section, MAP administers each step of the acquisition process for aerospace systems.

Some of the organizations of MAP are more well known than others. For example, many people are familiar with MiG fighters, the products of the Mikoyan-Gurevich Design Bureau. In general, more information is available on Soviet aircraft designers than on engine designers, and more information is available on engine designers than on component designers. This situation is especially true for civilian aircraft over military aircraft; the Soviets have, in the past, released very little data on military systems. The remainder of this section of the thesis describes each of the identified organizations known to play a role in the development and acquisition of aircraft engines in the Soviet Union.

Research Institutes

The scientific research institutes of the defense-industrial ministries and of the Soviet Academy of Sciences perform both exploratory and applied research in support of the experimental design bureaus. The major research institutes of MAP for propulsion research are the Central Institute for Aviation Motors and the Flight Research Institute (46:3,13). The Central Aerohydrodynamic Institute (TsAGI) is MAP's largest and oldest research institute, and directs nearly all Soviet aerodynamics research.

The Central Institute for Aviation Motors (Tsentralnii Institut Avaiatsionnogo Motorstroyenniya, or TsIAM) is the primary entity for air-breathing propulsion research in the Soviet Union (39:40). The institute, closed to Western visitors for decades, was recently visited by journalists from Aviation Week & Space Technology, a leading aviation magazine. The journalists were allowed to tour TsIAM's downtown Moscow scientific research center as well as its test branch located 20 miles outside the city. The downtown Moscow center includes departments specializing in large and small engine design, and departments for individual sections of engines, such as compressors, turbines, combustion chambers, and controls. The Moscow center also contains research laboratories, an experimental production shop, and a few full-scale engine test cells for small engines. Operation of the test cells is limited because of the center's urban location and age of the cells, so most test work is conducted in the branch facility outside Moscow. There, full-scale test cells can be used for all engine sizes to simulate flight conditions varying from Mach 1.2 at sea level to Mach 3 at 40,000 feet, and at altitudes up to 70,000 feet. The test branch also includes test rigs for individual engine components (40:40).

TsIAM Director Donat Alexeivich Ogorodnikov stated "this central institute contains the brains of the engine industry" (40:40). Comparing the Soviet organization with the U.S. industry, Ogorodnikov said:

> It's difficult to say whether the Western system or our system is better, but we are accustomed to our way. There is less competition here, but the central institutes concentrate all the experience and know-how of the industry. (40:40)

TsIAM's wealth of experience and knowledge were recently used to select which of two competing engine design bureaus would develop the engines for both the IL-96 and Tu-204 airliners. Ogorodnikov said not all of the engine designers are willing to accept help from TsIAM, and specifically mentioned General Designer Nikolai Kuznetsov, "who considers himself a strong engine designer. But life is showing he can't live without us" (40:40).

TsIAM's extensive resources and large research staff enable the center to perform several valuable functions in Soviet engine development. TsIAM researchers conduct basic research on engine design parameters and their effects on performance, and publish their results for use as guidelines by the engine designers. TsIAM performs tests on prototype engines for the engine designers as part of the acceptance testing required prior to approval for full-scale production. TsIAM's altitude simulation test facilities ensure that a prototype engine will perform well enough so that it may be safely mounted on a testbed aircraft for actual altitude testing. The sole organization in the United States resembling TsIAM in resources and function is the U.S. Air Force's Arnold Engineering Development Center at Tullahoma, Tennessee.

The Flight Test Station (also known as the Flight Research Institute, or LII) is located at Zhukovskiy airfield, an hour outside of Moscow. The heavily guarded complex is comparable to the U.S. Air Force's flight test organization at Edwards Air Force Base in California. The primary function of LII is the testing of prototype aircraft for the aircraft design bureaus to ensure airworthiness prior to approval for full-scale production (56:89). Additionally, specially configured Ilyushin IL-76 aircraft are used as testbeds for conducting flight testing of developmental aircraft engines (32:31, 21:51). These four aircraft, equipped with test instrumentation and data recording equipment, are used to "test and validate Soviet gas turbine engines up to 25,000 kgf (27:31). The engine test article is mounted at the port inboard position in place of one of the four Soloviev D-30KP turbofans.

Flight testing of engines is necessary to ensure that the prototype performs to requirements set forth by the customer. Flight testing of prototype engines is conducted in conjunction with bench testing of prototype engines at the design bureau's own facilities or those at TsIAM. Problems that appear during flight testing of a prototype article must be solved by the design bureau prior to state acceptance testing approval. Engines known to have undergone flight testing on LII's IL-76 testbeds are the giant Lotarev D-18T turbofan, the experimental Lotarev D-236 propfan, the Soloviev PS-90A turbofan, and the Isotov TV7-117 turboprop (27:31).

Engine Design Bureaus

The independent experimental design bureaus (opytno konstruktorskoye byuros, or OKBs) of the Ministry of

Aviation Industry are responsible for the overall development of aerospace systems and subsystems, from acceptance of initial tasking up to, but not including, series production. The engine development process itself was described in detail in the previous section. Each design bureau tends to specialize in the development of a specific type of product, for example, fighter aircraft, transport aircraft, transport engines, air-to-air missiles, etc. Since the Soviet design bureaus are government organizations functioning in an environment without private industry, they perform much of the work done by both the system program offices (SPOs) of the US Air Force System Command's Aeronautical Systems Division and the aerospace companies in US private industry. The focus of this paper is on the nine identified Soviet aircraft engine design bureaus.

There are three primary experimental design bureaus which develop engines for large Soviet transport aircraft: the Kuznetsov OKB, the Soloviev OKB, and the Progress OKB (40:40-41; 33:48). Some competition among the transport engine OKBs appears to exist, as described earlier in this paper by TsIAM Director Ogorodnikov, but the actual extent of competition is unclear.

The Kuznetsov Design Bureau was formed in the late 1940s at Kuibyshev. Nikolai Dmitriyevich Kuznetsov, a deputy designer under General V. Ya. Klimov during World War II, has headed the design bureau since its creation.

Between 1947 and 1952 the design bureau's first major design, the NK-12, was developed, and remains today the world's most powerful turboprop engine. In the 1960s Kuznetsov's design focus shifted to large turbofan engines. The Kuznetsov NK-8 family of turbofans includes the NK-8-2, which originally powered the Tu-154 airliner, the NK-8-4 on the IL-62 airliner, the NK-86 currently used on the IL-86 airliner, and the NK-88, a variant modified to burn liquid hydrogen and reportedly liquid natural gas (30:704-5). A derivative engine, the NK-144, is an afterburning turbofan that was developed to power the Tu-144 supersonic transport, and a NK-144 variant may power the Tu-26 bomber (30:705).

The engine design bureau in Perm headed by P.A. Soloviev from the early 1950s until last year is now led by General Designer Yuri E. Reshetnikov (32:17). This design bureau has been responsible for a number of very successful turbofans as well as a large turboshaft engine. The D-25V turboshaft engine powers several Soviet transport helicopters. The early D-20P and D-30 turbofans powered the Tu-124 and Tu-134 airliners, respectively. The D-30K series of turbofans, quite different from the D-30, is perhaps the most successful Soviet engine to date, and is used in the IL-62M and Tu-164 long-range civil transports, as well as the IL-76 military transport (30:704-705). Soloviev's last design, the PS-90A (formerly known as the D-90A), has been chosen over a competitor to power both the new IL-96-300 and Tu-204 civil transports (30:708; 40:41).

The Progress Engine Design Bureau, now headed by Fyodor M. Muravchenko, is located in the Ukrainian industrial city of Zaporozhye. The Progress OKB was originally known as the Ivchenko Design Bureau until Vladimir Lotarev succeeded upon Alexander Ivchenko's death in 1968. After Lotarev's retirement last year, the design bureau's name was changed to "Progress" (39:48). Under Ivchenko's leadership, the AI-25 and AI-25TL turbofans were developed. Lotarev led development of the very successful D-36 turbofan, which spawned a family of engines including the D-136 turboshaft on the Mi-26 helicopter, the new D-436M turbofan, the D-236 propfan demonstrator undergoing flight testing, and D-27 propfans for the new Yak-46 under development (37:29). Lotarev developed the D-18T, the Soviet Union's first high-thrust, high bypass-ratio turbofan powering the world's largest aircraft, the An-124 and An-225 derivative (39:48). The bureau is also responsible for the DV-2, a non-afterburning military turbofan developed for the Czechoslovakian L-39 jet trainer. The basic DV-2 core will be used in a family of variants, including an afterburning turbofan (DV-2F), a turboshaft (DV-12) and a medium bypass-ratio turbofan (DV-22) (52:16).

The Soviets have several new turbofan engines currently in development, as described in the preceding paragraphs. These engines, if successful, will greatly advance Soviet use of modern engine technology, such as full-authority digital electronic controls. In general, Soviet engine developments have lagged behind the West by a decade or more. A good example of this disparity is the Lotarev D-18T, the Soviets' first large high-thrust, high-bypass-ratio turbofan engine which appeared around 1983, nearly 15 years after the American C-5A Galaxy was flying on General Electric TF-39 high-thrust, high-bypass-ratio turbofans.

Historically, only two engine design bureaus have been responsible for development of engines for Soviet fighter aircraft: the Tumanskiy and Lyulka Design Bureaus. Both have developed afterburning turbojet engines, and both are now credited with low-bypass-ratio turbofan designs. Some news reports have credited a third design bureau, the Isotov Design Bureau, with the development of the same fighter engine as that credited to the Tumanskiy Design Bureau.

The Lyulka Design Bureau was headed by A. M. Lyulka from the mid-1940s until his death in June 1984. Lyulka was working on an axial turbojet design in the 1930s, but the events of World War II prevented its completion. His first major successful design was the AL-7 turbojet in 1954, followed by the AL-7F-1 afterburning turbojet. A later afterburning turbojet design, the AL-21F-3, powers several Sukhoi fighters (30:706). Recent information indicates the Sukhoi Su-27 interceptor is powered by two Lyulka AL-31F afterburning turbofan engines (1:29). The AL-31F engines were developed more than two decades after the AL-21F-3; no information is available to identify the bureau's activities during that period. Now known as the Saturn Design Bureau

(32:18) and headed by V. Chepkin (43:25), this Moscow-based organization is reportedly developing a non-afterburning version of the AL-21 military turbojet for a business jet, the Su-51, under development at the Sukhoi fighter design bureau (Sukhoi:90). Additionally, this design bureau is reportedly developing a turboprop engine, its first design in this class, for the Sukhoi Su-80 utility transport (Tup:92).

The Tumanskiy Design Bureau appears to be the most prolific Soviet engine design bureau. Originally known as the Mikulin Design Bureau, the name was changed in 1956 when A. A. Mikulin retired and Sergei Konstantinovich Tumanskiy succeeded him. Tumanskiy, a highly respected engine designer, died in 1973. During 1950-1951, Tumanskiy led the development of the Soviet Union's first turbojet of wholly Soviet design. Originally known as the AM-5, it was redesignated the RD-9 after Mikulin's retirement. The Tumanskiy Design Bureau developed the R-11 turbojet in 1953, which was later fitted with an afterburner and called the R-11F. In the late 1960s, the bureau developed the R-13, which replaced the R-11 in the MiG-21 fighter. The R-13 was followed by the R-25 turbojet, and later by the R-27 afterburning turbojet for the MiG-23 fighter. The R-29 family of turbojets, "one of the most important engines in the Soviet inventory," power most of the current MiG-23 and MiG-27 fighters (30:709). Tumanskiy developed the R-166 and R-266 engines fitted to record-setting Soviet aircraft

(30:709). Another Tumanskiy design is the R-195 nonafterburning turbojet on the Su-25 close air support aircraft (15:43). Some sources state the Tumanskiy Design Bureau is responsible for development of the RD-33 afterburning turbofan engine powering the MiG-29 fighter (40:41). At the Aeroengine '90 Exhibition in Moscow in April 1990, this organization was called the Soyuz Design Bureau and was credited with the development of the R27V-300 thrust-vectoring engine in the Yak-38 naval fighter (32:18).

The Leningrad design bureau formerly headed by Isotov was recently identified as the developer of the RD-33 turbofans in the MiG-29 FULCRUM fighter (32:17). This statement conflicts with an earlier source which gave the Tumanskiy Design Bureau credit for the RD-33 engine. The issue is significant in that the Isotov Design Bureau had previously concentrated its efforts on turboshaft engines, and its possible entry into the fighter engine arena is the first break in the historical pattern (of only two fighter engine design bureaus) for many decades.

The use of low-bypass ratio turbofan engines in fighter aircraft significantly decreases fuel consumption, consequently increasing combat range. The employment of low-bypass-ratio turbofan engines in Soviet fighter aircraft comes more than a decade after such use by the West. Possibly the first Soviet fighter with turbofans was the Su-27 FLANKER; the Su-27B version first flew in 1981 (56:75). The General Dynamics FB-111A was first flown in 1969 on

Pratt & Whitney TF-30 turbofans, followed in 1972 by the Navy's carrier-based F-14 TOMCAT (63:134). It appears the fighter engine design bureaus developed independently the turbofans for the new-generation fighters (MiG-31, MiG-29, and Su-27), without obvious assistance from the established turbofan engine designers, although a great deal of time was required to acquire the necessary expertise.

Of the remaining four engine design bureaus, the Isotov and Glushenkov Design Bureaus have developed both turboprop and turboshaft engines. The Koliesov Design Bureau has developed liftjets and a large turbojet. The Vedeneyev Design Bureau has developed several reciprocating engine designs for light aircraft (30:702-704,709).

The Isotov Design Bureau, headed by Sergei Pietrovich Isotov until his death May 1983, is now under the leadership of Alexander Sarkisov (32:17). Under Isotov, the bureau developed the TV2-117 and TV3-117 turboshaft engines which power most of the Soviet military attack helicopters. The Isotov TVD-850 turboprop was developed in an unsuccessful competition with Glushenkov for the An-28 aircraft (30:702). The most recent design, the TV7-117, may exist in both turboprop and turboshaft versions. The Ilyushin IL-114 transport under development will reportedly be powered by two Isotov TV7-117 turboprops (36:30). Two TV7s will reportedly power the Mil Mi-38 transport helicopter (34:5). Also, the Mil Mi-28 attack helicopter is described as having two TV7 turboshafts (22:46). As stated earlier, the

Leningrad-based design bureau may also be responsible for the development of the RD-33 turbofans in the MiG-29 fighter. Given the bureau's area of expertise in turboprops and turboshafts, and the Tumanskiy Bureau's expertise with turbojets and their fighter applications, the accuracy of these claims is somewhat questionable.

The Koliesov Design Bureau, which may have succeeded the Dobrynin Design Bureau in the late 1950s, first became known when it developed a large variable geometry engine for the Tu-144D CHARGER supersonic transport (30:704). This design bureau, called the Rybinsk Design Bureau at the Aeroengine '90 Exhibition, is responsible for the small RD-35-35FVR turbojets which give the Yak-38 naval fighter its vertical lift (32:18).

Little information is available on the Glushenkov Design Bureau; its location and current leader are unknown. Its past successful designs include the TVD-10B turboprop for the An-28 transport, the GTD-3 turboshaft used on the Kamov Ka-25 helicopter, and the TVD-20 turboprop which powers the An-3 biplane (30:702).

The Vedeneyev Design Bureau, led by Ivan M. Vedeneyev, has concentrated on reciprocating piston engines rather than turbine engines. The M-14P powers several Yak and Sukhoi light sport aircraft, while the M-14V-26 piston engine powers the Kamov Ka-26 helicopter (30:709).

Series Production Plants

A large number of series production plants for aircraft engines are subordinate to the Ministry of Aviation Industry. Thirteen such factories were represented at the Soviets' Aeroengine '90 Exhibition in Moscow in April 1990. These organizations are responsible for manufacturing the product in large numbers once engine designs have been successfully tested and approved by MAP, the customer and other government entities. The engine production plants are supported by other plants which manufacture various components for the engine. Military representatives are stationed at the production plants to ensure specifications are met.

The Zaporozhye Motorworks plant is the lead enterprise in the Motorstroitel Production Association which comprises four other plants and employs more than 50,000 people. The production association, headed by General Director Vyacheslav Aleksandrovich Boguslayev, who apparently succeeded long-time director Vasiliy Ivanovich Omelchenko (35:7), assembles engines such as the D-18T, the D-36, and the D-136, all of which were designed by the nearby Progress Design Bureau (33:49).

Pavel Fedorovich Derunov is the General Director of the Motor Building Production Association in the town of Andropov (formerly known as Rybinsk) (42:2). The association, formed in 1974, produces Soloviev D-30KU turbofan engines for use on IL-62M and Tu-154M civil transport aircraft (26:39). The association was noted for its massive retooling effort of the mid-1980s and its subsequent increase in productivity (42:2).

The Engine Building Production Association in Kazan, led by P. Viter, produces Kuznetsov NK-86 turbofans for the IL-86 airliner (45:1). The Krasnyy Oktyabr (Red October) Motor Building Production Association in Moscow was headed by V. V. Chernyshev until his death in the late 1980s (19:285). An engine plant in the eastern city of Tyumen was described in an article about extending engine life (41:2).

It is reasonable to expect the series production plants to feel the greatest effects of changes that will occur under perestroika, the current restructuring of the Soviet economy. The design bureaus most likely possess some of the most sophisticated equipment and the most skilled technicians in the Soviet aerospace industry. The creation of working prototypes from basic materials places priority demands on available resources. Many of the Soviet production plants are half a century old, employing more people than production levels require. Western visitors to some plants have observed equipment similar to that used in the United States in the late 1950s. Such inefficiency and obsolescence has attracted the attention of reform-minded central planners.

Summary

The development of aircraft engines in the Soviet Union involves the participation of many more organizations than does similar effort in the United States. The Soviet Ministry of Aviation Industry is a large government organization responsible for the research, development, testing, and production of aircraft, aircraft engine, and aerodynamic missile systems. Three separate types of organizations in the Soviet Ministry of Aviation Industry (the research institute, design bureau and production plant) perform the work done by each engine company in the United States. President Mikhail Gorbachev's restructuring of the Soviet economy will undoubtedly cause widespread changes in the operation of Soviet industry as a whole by forcing factories to operate more efficiently in the production of quality goods needed by consumers.

VI. Comparison with the USAF Engine Acquisition System

Introduction

The purpose of this section is to present an overview of the acquisition of aircraft engines by the United States Air Force in order to provide a basis against which the Soviet aircraft engine development and acquisition system may be compared. The use of the USAF engine acquisition system does not imply that this system is ideal, but rather it is the one with which the author and most readers are familiar and one in which they may have a reasonable degree of confidence. The major similarities and differences between the systems are presented in this section, along with some examples of significant engine development successes and problems.

The acquisition of aircraft engines by the United States Air Force involves organizations in both the government and in the private aerospace industry. The primary customers are the operating major commands of the U. S. Air Force: Tactical Air Command (TAC), Strategic Air Command (SAC), Military Airlift Command (MAC), and Air Training Command (ATC). The engine suppliers (developers and producers) are the aerospace divisions of major corporations which include General Electric's Aircraft Engine Business Group and United Technologies' Pratt and Whitney, as well as the smaller companies like Allison, Garrett, Williams, Teledyne, and Lycoming. The engine acquisition process is managed primarily by the Propulsion System Program Office (SPO) of Air Force System Command's Aeronautical Systems Division (ASD) at Wright-Patterson Air Force Base, Ohio.

New engines are developed in response to requirements for new capabilities (usually aircraft systems) rather than specific requirements for new engines. The development and acquisition process for each engine may be unique depending upon the circumstances; there is no single standardized and universally applicable engine development process followed in every case. Because engine performance is critical for mission accomplishment, because engines typically cost approximately 20 percent of the aircraft system price, and because engines typically require the longest lead times for development, aircraft engine development is now managed by the Propulsion SPO separately from the aircraft system (8;12;25). In some instances, engine/airframe integration or security concerns cause engine development responsibilities to be retained by the aircraft SPO. Research is continuously performed to further advance the propulsion technology base. Competition between engine contractors may be conducted, and the engine selected is delivered to the aircraft contractor.

USAF Engine Research

Air-breathing propulsion research for the U. S. Air Force is managed by the Aeropropulsion and Power Laboratory of the Wright Research and Development Center (WRDC) at

Wright-Patterson Air Force Base, Ohio. The Propulsion Lab conducts some basic research in combustor and compressor technology at Lab facilities; however, the majority of advanced research is contracted out to private engine companies (9). The technology developed by one engine company becomes government property, but is not shared with competing engine firms. The primary customers for lab-developed technologies are the AFSC product divisions, such as the Aeronautical Systems Division.

The Propulsion Lab receives approximately $6 million annually for basic research from the Air Force Office of Scientific Research (9). The Lab receives an additional $22 million per year for exploratory development and $50-60 million per year for advanced development work. Some funding for special projects is provided by the Defense Advanced Research Projects Agency (DARPA). The majority of profits enjoyed by the engine companies are made through commercial, not military, sales (8). Since military engine requirements continually demand state of the art technology and revolutionary advancements (through expensive research), where commercial engine requirements usually demand evolutionary advancements (25), the Propulsion Lab provides funding as incentive for research in areas of Air Force interest (9).

The engine companies do perform some basic research toward advancing the technology base for commercial engines, where they make most of their profits. Commercial technology developed by a company may be patented, providing an advantage over competitors and therefore serving as an incentive for engine companies to perform some basic research out of company discretionary funds. Such technology may later find its way into military engine requirements. For example, electronic engine controls were originally developed for the commercial engine sector and were later adapted for military use (9).

USAF Engine Development

The development and acquisition of major Air Force systems is governed by several government regulations, including the Federal Acquisition Regulation (FAR), Office of Management and BUdget Circular A-109, Department of Defense Directive 5000.1 (Major and Non-major Defense Acquisition Programs), Department of Defense Instruction 5000.2 (Defense Acquisition Program Procedures), and Air Force Regulation 800-2 (Acquisition Program Management) within the constraints of the Biennial Planning, Programming and Budgeting System (BPPBS) and the Six Year Defense Program (SYDP), which are not described in this thesis since its focus is not on the budget process. DODD 5000.1 establishes acquisition phases and milestone decision points, and also requires maintenance of a strong industrial base. Air Force Regulation 800-2 is the primary regulation governing the Air Force's acquisition of major new aerospace systems, including engines. New versions of DODD 5000.1 and DODI 5000.2 are currently in draft form, and if approved, will somewhat modify the existing defense acquisition process.

The development and acquisition of new engines by the U. S. Air Force begins with the identification of a requirement for a new aircraft capability (rather than solely for a new engine) by an operating command. Fighter engine acquisition is handled differently than transport engine acquisition. In the case of transport aircraft, the USAF generally purchases commercial aircraft systems that have been modified to USAF requirements. This type of acquisition allows the Air Force to save research and development costs that would be required for a new system. Since there are no commercial applications for fighter aircraft, the Air Force must follow the entire development and acquisition process.

For example, after threat analysis has been accomplished by the Foreign Technology Division, TAC may write a Statement of Operational Need for a new fighter with supercruise capability (as with the Advanced Tactical Fighter) to counter an increased threat. The SON does not propose solutions, it merely defines a need. From this need to cruise supersonically without afterburner, a new engine must be developed since that capability does not currently exist. The validated SON, which has been coordinated with Systems Command, Logistics Command and Air Training Command, is forwarded to Headquarters, U.S. Air Force, which transforms the SON into a Mission Need Statement (MNS), which is sent to the Secretary of Defense. If the Secretary approves the MNS, the new program is designated a major or non-major program at the first decision point, Milestone 0, and the program enters Concept Exploration.

The Secretary's decision is passed down to USAF, which writes the Program Management Directive, outlining the goals of the program. Next, Air Force System Command prepares a AFSC Form 56 implementing the PMD and establishing the aircraft system program office. The Propulsion SPO becomes involved generally when the aircraft system enters Demonstration/Validation after Milestone I. The Propulsion SPO creates the necessary performance specifications for a new engine in coordination with TAC and the newly established aircraft SPO. The engine requirements involve trade-offs among cost, life, and performance (8). The Propulsion SPO notifies prospective bidders among the engine companies first through the Commerce Business Daily. Those companies who responded then receive a formal Request for Proposal (RFP).

It should again be mentioned that engine development responsibility may sometimes be retained by the aircraft SPO. The determination on whether to retain control is made on a case-by-case basis. Currently, the ATF and B-2 SPOs managew their own engine programs (12).

After receiving the RFP, the companies develop proposals that are returned to the Propulsion SPO for evaluation. Separate contracts are let to specify the work each company will perform during each phase of the engine development, as well as the method of payment. The competing engine companies create full-scale working prototypes in the Demonstration/Validation (or Dem/Val) phase. The prototype engines are tested extensively under close scrutiny by the SPO. First, the engines undergo component testing, then full-scale testing at sea level conditions prior to simulated altitude testing at the Air Force's Arnold Engineering Development Center (AEDC) in Tullahoma, Tennessee. AEDC, considered an independent testing agency, records and reduces engine test data and forwards the results to the Propulsion SPO for analysis (12). Following ground testing, the engines are then subjected to flight testing. In the case of the competing ATF engine prototypes, each engine prototype will be transported to Edwards Air Force Base, California, for flight testing in each of the competing aircraft prototypes (12).

Once an engine selection has been made at the end of Demonstration/Validation phase, the engine contract specifications for the Full Scale Development (or FSD) phase are passed from the Propulsion SPO to the selected engine contractor. If the engine development was being managed by the aircraft SPO until this point, engine program responsibility may now be transferred to the Propulsion SPO. During FSD, developmental problems are solved. At the end of FSD, Low-Rate Initial Production of a small lot of engines is conducted. These engines are examined and tested for conformity with specifications, and the results are forwarded up the chain of commanded to the Secretary of Defense for a Milestone III decision. The Secretary's approval allows Full Rate Production of the engines. When the engines have been produced to Air Force satisfaction, each engine is accepted for the government by the appropriate Defense Plant Representative Office (DPRO) with a DD Form 250, at which point the engine becomes government property, and is then shipped to the chosen aircraft manufacturer as Government Furnished Equipment. The completed aircraft system is then deployed to the operating command. The aircraft system reaches Initial Operational Capability (IOC) when the first fielded unit is fully supplied with personnel, weapon systems, spares, auxiliary equipment, and training and repair manuals. At some point usually after IOC, the Program Management Responsibility Transfer (PMRT) is accomplished, in which program responsibility passes from Air Force Systems Command to Air Force Logistics Command.

At present, General Electric and Pratt & Whitney completely dominate the military aircraft engine business for fighter, bomber, and transport applications. The Air Force strives to encourage competition between the companies in order to advance the overall engine technology base, and to maintain the industrial base in this field, with the objective of obtaining the best possible engine at the best possible price. It is in the best interests of the Air Force to never let one of these two firms get too far ahead of the other, so that competition is maintained. Four months after Pratt & Whitney was awarded the F-100 contract for the F-15s and later the F-16s, General Electric received the contract to produce the F-101 engines for the B-1 (17:62).

As mentioned earlier, USAF engine development requires tradeoffs among cost, life and performance. Air Force engine acquisition, like acquisition of all major U. S. systems, is cost-driven, especially in the current era of decreasing defense budgets. Acquisition programs are reviewed on a yearly basis, and in order to meet budget shortfalls, acquisition schedules are sometimes slipped (extended). USAF philosophy demands long engine lifetimes, as Air Force engines must operate during lengthy periods of peace. The current reliability goals are 4000 hours for the engine hot sections (combustor and high pressure turbine), 8000 for the cold sections (fan and compressor) (9). In order to ensure mission success, whether aerial superiority or safe transport, the customer demands high performance requiring state-of-the-art technology. The F100 engine performance enabled the F-15 to achieve superior acceleration and maneuverability.

Comparison of USAF and Soviet Engine Acquisition Systems

The remainder of this chapter describes the similarities and differences between the Soviet aircraft engine acquisition process and that used by the U. S. Air Force. An analysis of the Soviet system (acquisition process and organizations involved) is presented in the following chapter.

Major Similarities. In both nations, vast resources in people, equipment, raw materials, and capital expenditures are required for the development and acquisition of aircraft engines. New engines are developed in response to validated customer requirements, usually as part of a demand for a new aircraft.

The acquisition process itself is somewhat similar in both countries, in that there are phased decision points set forth by law which require government/customer approval for continuation of the project. The recent requirements demanded by President Gorbachev's restructuring program that Soviet aerospace organizations must operate under the principles of economic accountability and self-financing are making the Soviet engine acquisition system more like the acquisition system employed by the U. S. Air Force than ever before.

Major Differences. The Soviet aircraft engine acquisition system varies significantly from the USAF system for engine acquisition. In the Soviet Union, there is no private aerospace industry as in the United States. Major system acquisition is conducted by government organizations for government customers. Each phase of aircraft engine development and acquisition is carried out by different organizations: research institutes, design bureaus, experimental production plants, and series production plants. In the United States, the private aerospace corporations perform most of their own research, and nearly all design/development and production (save what work may be subcontracted out to other firms).

The competitive environment of the U. S. engine industry induces each company to advance the "state of the art" and to be responsive to the needs of the customer. Although there is evidence of competition between Soviet design bureaus, the pressure for "corporate" survival does not exist, and there is little incentive to search for revolutionary improvements. Quite the contrary, the Soviet centrally planned system demands schedules be met, and designers and producers are reluctant to use risky new technology.

Soviet Engine Successes. Soviet engine "successes" are defined here as the fielding of significant new engine systems, and not as successfully meeting original customer performance requirements. Such original customer requirements and true performance data for Soviet engines are not available at the unclassified level.

One example of successful Soviet engine development is the Lotarev D-18T high bypass ratio turbofan, the first indigenous high thrust HBPR engine. This engine powers the four-engined Antonov An-124 "Ruslan", the world's largest operational cargo transport, as well as the larger, sixengined An-225 "Mriya" derivative. Although this development trailed by a decade and a half the development in the United States of the TF-39 for the C-5A "Galaxy," the D-18T may still be considered a success and has allowed the Soviets to take the claim for the "world's largest aircraft" away from the United States.

Several Soviet fighter aircraft are now powered by low bypass ratio turbofan engines with afterburners. The Sukhoi Su-27 FLANKER uses Lyulka AL-31 turbofans, and the Mikoyan MiG-29 FULCRUM uses Tumanskiy (or possibly Isotov) RD-33 turbofans. These engines were developed more than a decade after the Pratt & Whitney TF-30 turbofans were first employed in the FB-111 and later in the F-14. The use of the new turbofans in the current generation of Soviet fighter aircraft has provided them with increased performance and range over earlier aircraft with turbojet engines, and represents a significant advancement in Soviet air-breathing propulsion technology.

Soviet Engine Problems. The Ministry of Aviation Industry has suffered some problems with new engine development and acquisition. Perhaps most notable is the failure to develop a viable engine for the Tupolev Tu-144 supersonic transport (SST). The Tu-144, which first flew in December 1968, was originally powered by Kuznetsov NK-144 turbofans. When these engines proved unsatisfactory, the Kolesov Design Bureau developed a nonafterburning derivative engine, which was never able to reach full power. The Tu-144 was "quietly withdrawn from service" (55:156).

Other problems have been noted in the Soviet open press. The Kuznetsov NK-86 turbofans developed especially for the Ilyushin IL-86 civil transport are considered underpowered and inefficient, and there has been thought of re-engining the aircraft. Flight testing of the prototype Tupolev Tu-204 airliner was delayed by late delivery of its Soloviev PS-90A turbofan engines (38:44). Newly produced FLANKER fighters sat on the ground at the Komsomolsk factory awaiting engines (7:124). The Ministry of Aviation Industry was criticized in three separate issues of the newspaper Vozdushnyy Transport in the Fall of 1980 for failure to produce sufficient quantities of replacement engines and spare parts, which caused several airliners to be removed from service awaiting repairs (55:159).

The Cost of Engine Programs. The development and acquisition of aircraft engines by the U. S. Air Force demands a significant expenditure of resources. The U. S. Department of Defense awarded over $5.3 billion for engine development and production in fiscal year 1988 (20:95). The U. S. Air Force awarded General Electric a contract of nearly $400 million to produce 128 F110 engines for the F-16 fighter. Pratt & Whitney received a $444.2 million contract to produce 161 F100 engines for the F-15 and F-16 (20:94). Additionally, GE and its French partner in CFM, Snecma, received $267.4 million for re-engining the KC-135 tanker fleet (20:95). Both companies received $341.9 million to develop prototype engines for the Advanced Tactical Fighter and much more will be spent before the selected engine becomes operational (20:94). Engine development typically takes 13 years from basic research to production (9). The f.rst contracts for the ATF engines were let in 1983; the first operational flight is scheduled for 1997. It is estimated that over $1 billion will have been spent on ATF engine development prior to source selection, and that another $1 billion will be spent in Full Scale Development (12). The high cost of engine development prevents the government from allowing two engines to go into FSD. However, even after an engine selection has been made, future competition for each application is still possible.

In the absence of specific data on Soviet expenditures for aircraft engines, a rough estimate may be made through comparison with published U. S. figures. The United States spent approximately $5.3 billion of a $300 billion annual defense budget on military engines. Although American engines cost far more to develop and produce, they last far longer than Soviet engines, and the Soviets have more operational aircraft to equip. Some U. S. experts estimate total Soviet defense spending at between $250 and $350 billion (Power:32). With the assumption that the percent of the military budget for engines is aproximately equal in both countries (offsetting advantages in cost and life), then the Soviets may be expending nearly $4.1 billion annually on engine acquisition. While this comparison is admittedly of dubious accuracy (due to the difficulty in defining and estimating true Soviet costs, the different engine design approaches, and currency differences), it should be noted that the Soviet government operates more military aircraft than does the U. S., and each aircraft requires more engine spares due to shorter life, so that the assumption of equal percentages of defense spending for engines is reasonable. These figures do not include the cost of developing and operating engine design, development, test and production facilities, which are greater in number in the Soviet Union than in the United States. Nevertheless, maintaining an industrial and technology base to develop and produce modern high performance engines requires considerable expertise and expense, so that outside the United Staes and the Soviet Union, only France and the United Kingdom are successfully producing and marketing indigenous designs. With its greater numbers of engine facilities, greater numbers of military aircraft and required engine spares, the Soviet Union expends considerable resources to maintain an aircraft engine industry.

VII. Conclusions and Recommendations

Introduction

This section reports some conclusions which may be drawn regarding the strengths and weaknesses of the Soviet engine development and acquisition system and the performance of the Soviet engine acquisition system in fulfilling Soviet national objectives. Finally, this section makes recommendations for further research.

Analysis of System Strengths and Weaknesses

The Soviet weapon system acquisition process has a number of identifiable strengths. The multi-year funding of approved programs, combined with the tendency of engineers and technicians to remain with the same organization, provides a measure of stability in the form of design continuity and corporate memory not found in the U. S. system. The centralization of specialized research at large centers such as the Central Institute of Aviation Motor Building allows a national repository of expertise and information available to all engine designers, in stark contrast to the protection of proprietary information by each competing American engine company.

The Soviet system suffers from management deficiencies and momentum. In the past, such extreme emphasis was placed on meeting schedule deadlines and output quotas that little attention was given to quality. Although the weapon system designer was held responsible for the final product, the centrally managed Soviet defense industry has not, until now, fostered the kind of competition which has increased quality and advanced the state-of-the-art in the West.

The Soviet system of central planning generates a great deal of momentum. As described in an earlier chapter, once the system was prepared to develop and acquire the MiG-25 interceptor in response to a perceived threat from the USAF's XB-70 supersonic bomber, it was unable to stop this program after the XB-70 program was canceled.

Having different organizations perform the functions of research, design/development, and production causes serious transition difficulties for the Soviets. The Soviets have encountered major problems when responsibility is passed from the design bureau to the production plant.

One of the strongest criticisms of the Soviet system has been its tendency to discourage the use of advanced and relatively unproven technology in new weapon systems. The emphasis on meeting schedule deadlines, the lengthy tenure of conservative chief designers, the use of design handbooks of "approved" technology, the reliance on technology transfer from the West, all tend to inhibit innovation. Many people believe this conservative approach to design has caused Soviet technology to lag behind that of the West in many areas, such as materials.

Conclusions

Despite a complex and highly centralized bureaucracy composed of numerous party and government organizations with oversight responsibilities, the Soviet Union has been able to develop and deploy aircraft engines with sufficient performance capabilities to enable military and civilian aircraft to meet identifiable Soviet national objectives. Indeed, some U. S. experts believe the Soviet system has been more effective in producing effective and low-cost weapons than the United States, and question whether the U. S. has been able to compensate for numerical inferiority with qualitative superiority. Successful weapon system developments have given the Soviets increased confidence in their aircraft, as demonstrated by their willingness to participate to a far greater extent in Western aviation trade exhibitions. Additionally, the Soviets are now offering engines for sale outside the European Communist Countries.

Although some similarities between the engine acquisition systems of the United States and the Soviet Union exist, there are significant differences between the systems. Both systems are governed by regulations guiding the development and acquisition process and requiring government and customer approval at phased decision points before the project may continue to subsequent phases. In both systems, the military customer has a great deal of authority to demand satisfaction of its requirements. However, more organizations are involved in the Soviet acquisition effort than in the United States. Different organizations of the Soviet Ministry of Aviation Industry perform the functions of research, design/development, and production, thus complicating the process and introducing transition difficulties. In the United States, private engine companies perform all of these functions for Air Force engine applications under the management of the U. S. Air Force laboratories and system program offices. Soviet engine developers enjoy multi-year funding which allows greater project stability than is found in the U. S. Air Force acquisition effort (in which the system program office must endure yearly funding appropriations).

Historically, the lack of true competitive forces in the Soviet Union and the emphasis on meeting schedules has tended to drive the system to adopt low-risk, evolutionary changes in the advancement of weapon systems technology. Designers in the Soviet Union were therefore less likely to use new technology than their American counterparts, who use new technological capabilities as a selling advantage. This position has caused the Soviets to lag behind the United States in most areas of propulsion technology, such as materials. Also, at least prior to perestroika, Soviet design organizations did not have to constantly develop new engines to survive: the Lyulka Design Bureau developed no identified designs for nearly two decades between the AL-21F and the AL-31F. American engine companies could not remain in business at that low activity level. The self-financing requirements of perestroika are affecting the operations of research institutes, and will likely affect the engine designers in the form of increased competition for resources.

Soviet engine design philosophy has varied greatly from U. S. design philosophy. Soviet doctrine has emphasized readiness for war. Soviet engines have therefore been designed for wartime operation; since attrition is expected to be high, no emphasis is placed on long engine life. Soviet engines have been rugged and simpler in design, having fewer parts than comparable American engines. American design philosophy has emphasized life cycle cost, so that engines have been designed for reliability and long life during lengthy periods of peace. American designs have been far more complex than Soviet designs, and use the very latest state-of-the-art technology to ensure performance and reliability, at the price of greater unit cost.

Soviet weapon systems have necessarily become more complex (though less so than comparable Western systems), requiring longer development times and more capital expenditure than previous designs. While Soviet engine developments such as high-thrust, high bypass ratio turbofans for large transports and low bypass ratio turbofans for fighters have lagged similar developments in the United States by more than ten years, the Soviets are closing the "qualitative gap" in aerospace technology that many people once believed the U. S. Air Force enjoyed. Changes to the Soviet aircraft engine industry and the entire Soviet weapon system acquisition process, including decreased military spending, self-financing and increased production of consumer goods, appear to be forcing the Soviet system to operate more like the USAF system. In addition to the increased military threat from Soviet aircraft with increased propulsive capabilities, the Western world may one day face commercial competition from the Soviet aircraft engine industry.

Recommendations

The dramatic events now occurring in the Soviet Union, and particularly those affecting the Ministry of Aviation Industry, warrant a future review of Soviet engine development and acquisition practices which might be modified under the perestroika and konversiya reforms. The principles of economic accountability and self-financing currently being imposed on the organizations of the Soviet aerospace industry will undoubtedly have a major impact on their operations, as many are now seeking new markets, even in the West, to obtain additional financing. In addition to being a potential military adversary, the Soviet Union may in the future become a serious business competitor. Current challenges to the Communist Party controlling the Soviet government may one day result in a multi-party system, an occurrence which could greatly affect the development and acquisition of Soviet aerospace systems. These factors suggest additional research on the Soviet aircraft engine industry be conducted to analyze and report how the process for Soviet engine development may have been changed.

Appendix A: Soviet Aircraft Engines

Design Bureau (Location)	Engine	Type	Maximum Thrust (lb)	Takeoff Power (hp)	Aircraft Application
Progress	D-36	turbofan	14330		An-72/74 COALER
(Zaporozhye)	D-136	turboshaft		11400	Mi-26 HALO
	D-18T	turbofan	51650		An-124 CONDOR
	D-436M	turbofan	16500		(Tu-334)
	DV-2	turbofan	4800		Czech L-39
	D-27	propfan	(24600)	13000	
Soloviev	D-20P	turbofan	11905		Tu-124
(Perm)	D-25V	turboshaft		5500	Mi-6 HOOK
	D-30KU	turbofan	24250		IL-62M
	D-30KP	turbofan	26455		IL-76 CANDID
	PS-90A	turbofan	35300		Tu-204, IL-96
Kuznetsov	NK-12M	turboprop		14975	Tu-95 BEAR
(Kuybyshev)	NK-8-2	turbofan	20950		Tu-154
	NK-8-4	turbofan	23150		IL-62
	NK-144	turbojet	44090		Tu-144 CHARGER
	NK-86	turbofan	28660		IL-86
Lyulka	AL-7F	turbojet	19840		Su-7 FITTER
(Moscow)	AL-21F-3	turbojet	24700		Su-17 FITTER C
	AL-31F	turbofan	27500		Su-27 FLANKER
Tumanskiy	R-11F	turbojet	12676		MiG-21 FISHBED
(Moscow)	R-13	turbojet	14550		MiG-21 FISHBED
	R-266	turbojet	27010		MiG-25 FOXBAT
	R-25	turbojet	16535		MiG-21 FISHBED
	R-27	turbojet	22485		MiG-23 FLOGGER
	R-29	turbojet	21825		MiG-23 FLOGGER
	R-195	turbojet	9900		Su-25 FROGFOOT
	RD-33	turbofan	18300		MiG-29 FULCRUM
Isotov	GTD-350	turboshaft			Mi-2
(Leningrad)	TV2-117	turboshaft		1700	Mi-24 HIND
	TV3-117	turboshaft		2200	Mi-17 HIP
	TV7-117	turboprop		2500	IL-114
	TV7-117	turboshaft		3200	Mi-28 HAVOC
Koliesov	RD-36FVR	liftjet	6725		Yak-38 FORGER
Glushenkov	TVD-10B	turboprop		960	An-28
	TVD-20	turboprop		1450	An-3
Vedeneyev	M-14V-26	piston		325	Ka-26
	M-14P	piston		325	Su-26, Yak-55

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Vita

Captain Dale S. Gabriel [redacted]. He graduated from John Marshall High School in San Antonio in 1980 and attended Texas A&M University in College Station, Texas, graduating in May 1984 with a Bachelor of Science in Aerospace Engineering (specialty: Propulsion). Upon graduation, he received a regular commission in the United States Air Force and was assigned to the Foreign Technology Division (FTD) of Air Force Systems Command at Wright-Patterson AFB, Ohio. For the last four of his five years as an intelligence analyst at FTD, he was responsible first for evaluation of Soviet air-breathing design and development facilities and capabilities, and then for both Soviet air-breathing and rocket propulsion development facilities and capabilities. He wrote the first comprehensive Defense Intelligence Agency review of Soviet air-breathing propulsion development facilities, and served for a year as the Air Force representative to the Soviet Processes and Resources working group of the Scientific and Technical Intelligence Committee. He entered the School of Systems and Logistics, Air Force Institute of Technology, in May 1989. Captain Gabriel is married and has a son.

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13. ABSTRACT *(Maximum 200 words)* This thesis examined at the unclassified level the Soviet aircraft engine development and acquisition process, as well as the roles of the organizations involved. It also examined how well the Soviet system appeared to be capable of fulfilling Soviet national objectives. The U. S. Air Force engine acquisition system was used as a basis for comparison. The highly centralized Soviet weapon system acquisition process is currently controlled by the Communist Party of the Soviet Union. The Uniform System of Design Documentation mandates a series of development stages which must be performed. The development and acquisition of aircraft engines takes place entirely within the Soviet government: no private engine industry exists. Research, design/development, and production of Soviet aircraft engines are performed by separate organizations within the Ministry of Aviation Industry. The successful developments of large turbofans for transports and smaller turbofans for fighters indicate a significant capacity to produce advanced systems representing an increased military threat to United States forces in potential future conflict. The current industry restructuring efforts are moving the Soviet system closer to that employed by the U. S. Air Force.

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