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21969

CIA SR 79-10141

Soviet Military Aircraft Maintenance

An Intelligence Assessment

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Soviet Military Aircraft Maintenance [redacted]

An Intelligence Assessment

Information available as of 1 September 1979 was used in the preparation of this report.

The author of this paper is [redacted] Office of Strategic Research. Comments and queries are welcome [redacted]

This paper was coordinated with the National Intelligence Officer for General Purpose Forces. [redacted]

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Preface

This paper is an outgrowth of ongoing efforts by the [redacted] the Office of Strategic Research to estimate the annual costs of Soviet defense. Valuing the USSR's military activity in monetary terms has led us to assemble a large all-source data base from which we cull the salient characteristics of Soviet defense programs. In this process, we frequently gain special insights into a particular program or activity and are able to develop a unique overview of its operation. Often this information is of interest to the Intelligence Community for reasons beyond its value in supporting our expenditure estimates. This report is one of these overviews. ([redacted]

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Soviet Military Aircraft Maintenance

Overview

The Soviet military aircraft maintenance system is characterized by:

- A philosophy that emphasizes regular preventive maintenance, replacement rather than field repair of defective parts and components, periodic rebuilding of entire airframes and engines, specialization by maintenance personnel, and conservative scheduling of maintenance. This is similar to the maintenance philosophy for most other major items of Soviet military and civilian equipment.
- Maintenance operations that are strictly keyed to extremely conservative specifications. The Soviets purposely keep maintenance intervals short and adhere to them rigidly to minimize premature failures and to simplify maintenance planning.
- A highly structured maintenance organization that is characterized by extreme specialization of tasks and the performance of all complex repair—including overhauls—in rear-area plants and factories.

By emphasizing narrow specialization and directing major repair work to assembly-line plants in rear areas, the Soviets have solved some of the problems inherent in maintaining high-performance jet aircraft that might otherwise have plagued them. In particular, they have adapted their military aircraft maintenance system to the mass-production orientation of their economy and to the constraints arising from their reliance on short-tenured conscripts to man 70 percent of their air and air defense forces.

Although the ruggedness and technical simplicity of most Soviet military aircraft tend to make them relatively easy to maintain, the Soviets' conservative approach to maintenance, with its emphasis on frequent and extensive overhauls for airframes and engines, makes the system very costly. We estimate that:

- In 1979 the Soviet Ministry of Defense will spend between 7 and 8 percent of its estimated defense budget to maintain aircraft.
- Expressed in terms of equivalent 1978 prices as paid by the US Department of Defense, Soviet military aircraft maintenance might cost 6-7 billion dollars. This is roughly double the amount the US Air Force might need to maintain (with current US methods) a similar fleet—that is, one with comparable numbers of aircraft, technical characteristics, and operating rates.

The Soviet military aircraft maintenance system appears to operate well enough in peacetime to guarantee commanders the level of readiness they desire. The system, nevertheless, seems to reflect the Soviet view that any major conflict would be intense and brief.

- Its inherent conservatism and redundancy regularize the flow of maintenance work and ensure that an adequate number of combat-ready aircraft will be on line at any time.
- The brief intervals between major maintenance, combined with intentionally low operating rates—usually no more than one-half the rates for comparable USAF aircraft—mean that most Soviet aircraft within combat units are relatively new or freshly overhauled and, thus, far from the point where mechanical failure could be expected.
- The high level of readiness of combat aircraft and the large front-line inventories of aircraft and spare parts probably make the Soviet maintenance system adequate to support the first few weeks of a wartime surge.
- In a protracted war with high attrition rates and disrupted supply lines, the rear orientation of the system would probably be a liability. Soviet air regiments by themselves lack the capability to handle the heavy flow of complex repair tasks that would result from battle damage.

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Philosophy and Structure of the Soviet Military Aircraft Maintenance System

Philosophy

The Soviet maintenance philosophy for aircraft is similar to that for other major items of military equipment. The Soviet armed forces emphasize regular preventive maintenance, replacement rather than repair of defective components and parts, periodic rebuilding of entire airframes and engines, specialization by maintenance personnel, and relatively frequent scheduled maintenance and overhauls.

Preventive Maintenance. The Soviets emphasize frequent technical servicing and preventive maintenance for several reasons. These are, of course, essential to maintaining equipment at a proper state of readiness. In addition, Soviet aircraft require more routine "fiddling" (checking, lubrication, and adjustment) than do most US aircraft of similar performance and mission. This results in part from quality control problems in their manufacture and the greater use of mechanical, rather than automated and solid state, assemblies and controls. In addition, the Soviet military does not appear to feel the manpower constraints experienced by most Western armed forces. With a large body of conscripts to be kept occupied, busy work is an advantageous tool for familiarization and training.

Replacement Rather Than Repair. Preference for replacement over repair, to a large extent, follows from the structure and organization of the Soviet economy, which favors the performance of complex mechanical work at large, specialized, factory-like plants. The Soviet military shares this preference, because replacement of parts (whether defective or at the ends of their service lives) requires less discretionary judgment (and, usually, less technical skill) on the part of regimental maintenance personnel than trying to fix them. This is an advantage for a largely conscripted force—draftees make up about 70 percent of the Soviet air and air defense forces—with short terms of service and limited training opportunities. Replacement rather than repair also helps to ensure day-to-day readiness of equipment and makes for easier long-range planning of maintenance requirements.

Rebuilding. In keeping with Marxist-Leninist economics, the Soviets view the periodic overhaul of capital equipment (including aircraft) as a remanufacturing process, which restores an item's original productive value. Soviet military planners see their capital repair program as a means of making sure that all equipment has its original productive value—which, in military terms, is to be combat ready.

Soviet overhaul practices run counter to the US philosophy of not tampering with things that work properly and of restricting overhaul to components that actually need it. The costly Soviet practice would not be tolerated in most Western economies, but it seems to pose few problems—as yet—for the USSR's economy. From a US military point of view, the mandatory periodic rebuilding of an aircraft would be regarded as inefficient, financially wasteful, and probably dangerous.

Specialization. The Soviet armed forces stress specialization of tasks and the development of narrowly focused technical proficiency of maintenance personnel. Maintenance and overhaul units are organized according to specialty into separate shops and task groups, and maintenance technicians are encouraged by their commanders, the military press, and the party to become masters of their jobs. Maintenance manuals for Soviet aircraft outline in minute detail when and how all procedures are to be performed. Rigid schedules leave little room for discretion on the part of maintenance personnel as to whether components should be repaired or replaced. Complex components are removed from the aircraft, crated, and either sent to a repair plant or returned to the factory for servicing and overhaul. Factory technicians are sometimes brought into the regiment or the repair plant to help with particularly complex or sensitive maintenance tasks, especially those on new aircraft models. The cumulative thrust of this stress on specialization is to simplify the maintenance process.

Scheduling. Soviet military aircraft maintenance schedules are set very conservatively. Comparison of maintenance and replacement intervals for military aircraft with those for like-model civilian aircraft indicates that the Soviet armed forces employ shorter intervals and enforce them more rigidly. In part, this may be an attempt to tailor the maintenance frequency to the military's high sortie rates and more rigorous flight profiles.

In any event, the Soviets seldom seem to find it necessary to replace components before their scheduled times for inspection or removal.[1] This eliminates much uncertainty in the maintenance planning process, simplifies repair tasks for regimental maintenance personnel, and helps minimize unanticipated downtime resulting from premature failures.

Categories

The Soviet military defines four categories of aircraft maintenance: routine (or current) repair, technical servicing and inspection, medium repair, and capital repair. These categories are similar for vehicles, land arms, ships, and aircraft.

Routine Repair and Technical Servicing. Routine repair refers to the adjustment, repair, and replacement of components and assemblies that break down in day-to-day operations. It includes replacement of components that fail before the expiration of their service lives or before they reach the time for scheduled removal and overhaul. Routine repair is performed as needed, usually at the same time as the scheduled inspections and technical servicing of the aircraft.

[1] The military does experience premature failures: their maintenance intervals, however, are so short that premature failures are seldom disabling and often can be corrected during normal, planned maintenance actions.

In contrast, technical servicing is a planned maintenance action. It consists of the periodic servicing, calibration, and lubrication performed at specified intervals in conjunction with detailed inspections of the aircraft and its main components. Because routine repair and technical servicing are performed concurrently, Soviet maintenance planners group them together.

Medium and Capital Repair. Medium repair—referred to as *srednyy remont* (or, for aircraft, sometimes *profilakticheskiyy remont*)—involves replacement of a limited number of principal components, which are subsequently overhauled (if time remains on their service lives) or scrapped. Although once a distinct category of maintenance—classed as a minor overhaul—medium repair of Soviet aircraft, particularly in the military, has gradually become merged with routine repair and technical servicing. At present, it is normally performed in conjunction with the last major inspection conducted at the airfield (although, for civilian aircraft and non–Soviet Warsaw Pact military aircraft, it is frequently still done at a repair plant).

Capital repair—referred to as *glavnyy remont* (or *kapitalnyy remont*)—involves a major overhaul and rebuilding of an aircraft or an engine and the replacement of all components whose service lives have expired. Unlike medium repair—which, for military aircraft, has become a unit-level component exchange operation— capital repair is always performed at the factory or a repair plant and consists of an extensive reworking of all systems.

Modernization and Modifications. In both military and civil aviation, the Soviets consider modernization and modification to be an integral part of the aircraft maintenance program. During routine maintenance and overhaul, technicians strive to enhance the performance and maintainability of the aircraft by installing up-to-date replacement parts and incorporating, wherever feasible, the latest design features specified by the manufacturer. The Soviet military regards this process as critically important for readiness.

Major modifications, however—those that significantly alter the performance or mission capabilities of a given aircraft—are not considered part of maintenance. If such alterations are made, the Soviets generally redesignate the aircraft as a different model.

Norms

Resource and Service Life. With the exception of current repair, most Soviet aircraft maintenance operations are performed in accord with strict schedules keyed to a designated "resource" (*resurs*) and "service life" for each major component of the aircraft. The *resurs* is the equivalent of the US "time before overhaul" (TBO). The service life is the total time that an item can remain in use; it is calculated to be somewhat less than the time when the item would normally fail and be unrepairable.

The Soviets specify the *resurs* (TBO) and service life in operating hours and chronological age. The TBOs and service lives vary from one aircraft model to another. These norms determine precisely when all major maintenance operations are performed and components are exchanged. The schedule for technical servicing and inspection, however, is more nearly uniform for all aircraft models.

TBOs and service lives for aircraft and engines are set at the factory and are guaranteed by the manufacturer through a written warranty. For a newly introduced aircraft model, these are set extremely low. As the production run lengthens and maintenance histories accumulate, the factory gradually lengthens the TBO and service life norms.[3] An increase in these norms will apply to all units in that model run, irrespective of when they were manufactured—on the condition that the servicing and overhaul of each aircraft have been kept up to date. This condition ensures that the aircraft will have undergone all appropriate modifications; if it has not, liberalized maintenance norms could impose a dangerous strain on unmodified components.

[3] Not to be confused with this trend of gradually increasing TBOs and service lives during the production cycle of an aircraft model is the phenomenon of decreasing time between overhauls for an individual aircraft. As an aircraft or engine progresses through its service life, the anticipated mean time between failures slowly becomes shorter as a result of normal mechanical wear and progressive metal fatigue. The Soviets appear to allow for the increasing likelihood of breakdown by keeping the *resurs* of an item low and also by incorporating a discretionary range (usually ± 5-10 percent) in it.

Soviet TBO and service life norms are set on the basis of theoretical testing and actual maintenance experience. These norms are principally functions of design, materials, and quality control.

The Soviets recognize that certain design bureaus and factories turn out better products than others. Among engines for fighter aircraft, for example, those designed by Tumanskiy are most highly regarded, and our analysis indicates that TBOs and service lives for engines from that bureau are usually longer than those for comparable engines from other designers.

Materials and quality control appear to be even more important. The Soviets still suffer from technological shortcomings in such areas as metallurgy, bonding, and composites, which place limitations on the maintenance lives of their aircraft. Likewise, Soviet manufacturers have found that the TBO and service life norms for their aircraft—which are usually quite low by Western standards—can often be doubled or tripled if they simply upgrade workmanship and quality inspection. Often an aircraft manufacturer will offer two versions of the same product, which differ only in the quality control exercised in their manufacture. The version with the better workmanship has an increased service life—and a higher price.

Manufacturers have a stake in keeping norms for service lives and TBOs set conservatively. They guarantee their products to perform to these norms. If premature failure occurs, the manufacturer is responsible for damages and may, if the aircraft was produced for the military, be subject to a stiff fine.

On the other hand, Soviet planners are well aware that short TBOs and service lives reduce aircraft productivity and thus diminish military readiness. Since the early 1960s, the Soviets have made a concerted effort to lengthen maintenance and replacement intervals, primarily by using more durable materials and applying better quality standards.

Planning. In planning for technical servicing and capital repair, the Soviets differentiate between the aircraft itself—which includes the airframe, avionics, and fixed weaponry—and its engines. They do so because Marxian economics classes them as discrete items of productive capital. Consequently, each aircraft has two separate master maintenance schedules: one for the engine or engines and one for everything else.[3] These two schedules are not always fully integrated, a factor which probably results in some unnecessary downtime. There is little indication that the Soviets see this as a problem.[4] [redacted]

Apart from the peculiarities of Soviet economics, there is a practical reason for having separate aircraft and engine maintenance schedules: the disparity between the two in service lives and required maintenance frequencies. Normally, the Soviets figure the service life of an engine to be 25 to 50 percent of that of the airframe. In addition, a typical airframe may be allowed five or more overhauls, but the engines are seldom permitted more than two or three. A Soviet aircraft that lasts to the end of its service life (and most of them probably do) will usually require at least five separate engines (as either direct replacements or maintenance spares) for each of its engine beds. [redacted]

TBOs and service lives, as previously noted, are set in terms of both calendar years and operating hours. Calendar years are important because deterioration and metal fatigue are aggravated by age, but, for most aircraft, annual operating hours are the crucial measure for determining when the various types of maintenance are performed. For an airframe, the operating rate equals hours spent in flight. For an engine, the operating rate includes not only flying time but also time spent running on the ground—whether in warmup or servicing. For a high-performance fighter, the norms are set in regular operating hours and afterburner hours. [redacted]

[3] The Soviets also follow separate subschedules for major components such as the electrical system and the radar, but these are generally adjusted to fit into the master schedule for the airframe. [redacted]

[4] One reason for this unconcern is the speed with which engines and other major components can be changed on most aircraft models at the operating level. Where engine changes are not easy—in the MIG-21 (Fishbed), for example, whose engine is integrally mounted with the fuselage—it appears that a conscious attempt has been made to mesh the aircraft and engine maintenance schedules. [redacted]

The Soviets recognize that operating hours alone are not always the best indicator of when maintenance should be performed on a modern, turbine-engined aircraft. Particularly for military aircraft which fly frequent, high-performance sorties, the frequency of takeoffs and number of engine cycles are also important. In recent years, for example, the US Air Force has begun to set maintenance schedules geared to these measurements. Soviet military and civil aviation planners, however, cling to operating hours as the determinant of the maintenance schedule but take mission profiles and sortie rates into consideration when they compute them Soviet maintenance schedules, consequently, *do* indirectly reflect the number of takeoffs for a particular aircraft in a given role. In addition, existing maintenance schedules (in operating hours) are already drawn conservatively enough to ensure that aircraft usually are serviced before mechanical trouble develops. [redacted]

Organization

Air Regiments. For the Soviet military, the air regiment constitutes the basic fighting and maintenance unit. The regiment organizes its operations around a series of alternating flying and servicing days, with detailed planning done on a weekly basis. Aircraft maintenance, up through medium repair, is performed by the regiment under the supervision of the regimental engineer (usually a lieutenant colonel), who is also deputy commander for aviation engineering services. [redacted]

The regimental maintenance organization is a tiered system in which one echelon supports another. Servicing and repair that cannot be performed by one level are passed up to the next. [redacted]

An air regiment is divided into three flying squadrons and a technical exploitation unit, referred to as the "TECh." The TECh typically is commanded by a major who reports directly to the regimental engineer. It is the primary maintenance arm of the regiment and is organized into separate shops for the repair of engines, armament, safety equipment, electrical equipment, radios and radar, and, where appropriate, photoreconnaissance equipment. The TECh is responsible for performing major inspections, medium repair, and current repair that lower echelons cannot handle. If an aircraft cannot be taken to TECh facilities, the TECh can organize portions of its crews into a mobile maintenance group, known as the "PARM," transported in vans.

Each flying squadron consists of a flight branch (divided into four flights) and a technical branch. The technical branch—usually headed by a captain or major, who reports to both the squadron commander and the regimental engineer—is organized like a miniature TECh, with separate crews for engines, armaments, electrical equipment, and radios and radar. The squadron technical branch—not to be confused with the regimental TECh—is responsible for minor current repair and technical servicing.

The flights are composed of flying teams and servicing teams. Each servicing team usually consists of an officer whose rank is equal to that of the flight team pilot (usually a lieutenant or senior lieutenant) and at least two technicians. The maintenance team (or crew) is responsible for the preflight and postflight inspections and preparation of the aircraft in the regimental inventory to which it is assigned.[3]

Air Technical Battalions. A military airfield is operated by an air technical battalion (*obato*). The *obato* is organizationally distinct from the air regiment and performs functions separate from those of the regimental maintenance organization. The responsibilities of the *obato* are logistic and personnel support: maintenance of facilities, runways, and vehicles; provision of food, medical, and housing services; and management of supplies and spare parts. In general, the *obato* is not involved directly in the maintenance of aircraft, but its logistic work is an essential prerequisite to the proper functioning of the regimental maintenance organization.

[3] Unlike the situation in the US Air Force—where enlisted personnel supervise and perform virtually all hands-on maintenance procedures—Soviet commissioned and warrant officers often work alongside conscript technicians in performing even routine tasks.

Figure 1

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Military maintenance technicians inspecting a TU-22 Blinder.

Overhaul Plants. The capital repair of engines and aircraft is performed both at the factories where they were produced and at a series of aircraft and engine repair plants run by the Ministry of Defense and located throughout the USSR. On occasion, military aircraft are overhauled at civilian-run repair plants, and civil aircraft may be overhauled in military facilities.

The Ministry of Defense overhaul plants, though commanded by uniformed military personnel, are staffed primarily by civilian technicians. They are probably operated on an enterprise—*khozraschet*—basis. Each Soviet air army has a number of these plants subordinate to it, with each plant specializing in the repair of a particular type of aircraft (for example, fighters, bombers, transports). Aside from doing capital repair, these plants also perform specialized repairs and modifications that are beyond the capability of air regiment maintenance staffs.

Effectiveness

In peacetime the Soviet aircraft maintenance system seems to operate well enough to guarantee military commanders the level of readiness they desire. During a protracted war, the system could prove vulnerable.

The servicing and replacement of components in advance of expected failure and at intervals shorter than required by normal wear may seem inefficient by US standards, but it probably assures the Soviets that a sufficient number of serviceable aircraft will be available when required. The system helps keep premature aircraft failures to a minimum and, thereby, makes maintenance operations predictable and simple. When the conservative maintenance norms are coupled with the intentionally low annual operating rates for most Soviet military aircraft—usually no more than one-third to one-half the rates for comparable US military aircraft—they ensure that the Soviets have a combat-ready fleet of relatively new and recently overhauled aircraft that is far from a point where mechanical failure might occur.

The quality of Soviet regimental maintenance personnel seems to be more than adequate for their assigned tasks. The Soviets emphasize both professionalism and expertise to their maintenance engineers—and appear to get it. Limitations inherent in the use of short-tenured conscripts are compensated for by the functional compartmentation of the maintenance system and the routinized, cookbook nature of most maintenance operations. The Soviet practice of making maintenance teams, parallel to the flying teams, responsible for particular aircraft appears to be a good way of ensuring personal accountability for servicing and repair work. Such accountability is necessary because—despite official propaganda—maintenance personnel are held in lower esteem than their flying colleagues, and they appear to suffer from a lack of hands-on training before their assignment to line jobs.

In the event of war, the organization of the Soviet aircraft maintenance system—with its many tiers and its concentration of specialists and specialized equipment in rear-area repair plants—could cause a problem of sustainability, particularly if supply lines were cut and the conflict lasted for more than a few weeks. Although trained and equipped well enough for routine, peacetime tasks, the regimental maintenance organization is probably not adequate for handling the heavy flow of unpredictable and complex repair jobs that might arise during an extended period of warfare. Then the Soviet dependence on rear support for major maintenance work—although initially offset by the sheer magnitude of the military air order of battle—could prove to be a serious liability in a NATO-type conflict that was not swiftly resolved.

Cost Implications

Maintenance Cost Planning

The Soviet armed forces, we believe, calculate the annual costs of maintaining their aircraft fleet in much the same fashion as civil aviation enterprises like Aeroflot.[6] Their approach is to make a life-cycle cost estimate for each aircraft at the time of its procurement and then to adjust this estimate annually to account for changes in operating rates, technical characteristics, maintenance norms, and the price of spare parts.

In the Soviet approach, the amount budgeted annually to maintain an aircraft is an even share of the lifetime cost of providing inspections, technical servicing, current repair, and overhaul for its airframe, avionics, and engines. These costs are estimated as a fixed percentage of the procurement price (or average wholesale valuation when new) of the aircraft. Total maintenance cost becomes, therefore, a function of the type, size, and complexity of the aircraft, its annual operating rate, its service life, and the time norms governing its maintenance. The procurement cost of the aircraft is used as an index of its complexity. By current US standards, this is a valid way to estimate maintenance costs—although it differs considerably from the method that is now in use in the US Air Force.[7]

We have approximated the Soviet maintenance cost estimating relationships (CERs) by using data available in Soviet open-source treatises on the economics of air transport and combining it with information

[6] See appendix A for a more detailed discussion of the Soviet cost estimating procedure.
[7] Typically, USAF maintenance cost planning factors are peculiar to an aircraft model, its role and mission, and the theater of operations where it is used. Annual flying time is the principal independent variable in the US formulations.

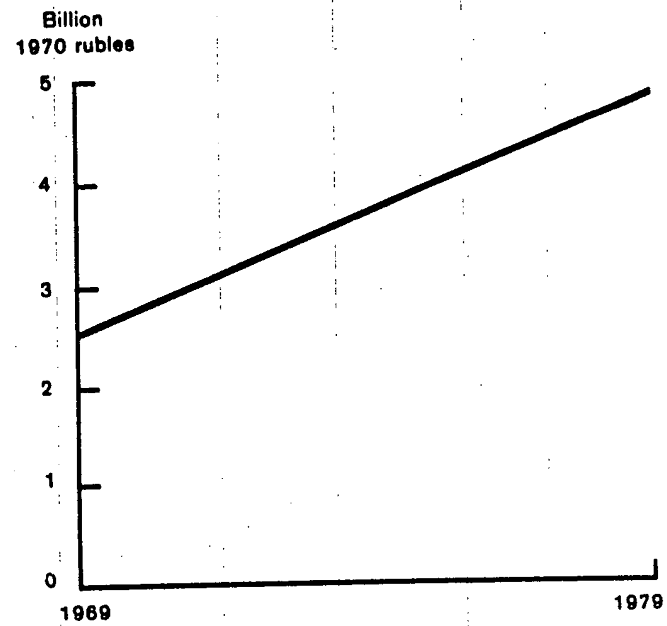
provided by all-source intelligence on Soviet military aircraft and their maintenance characteristics. A comparison of the results provided by our CERs with actual maintenance costs reported by the Soviet military confirms that our CER approximations are generally reliable estimators of the actual costs of military aircraft maintenance in the USSR.

Estimated Maintenance Costs

Our reconstruction of the CERs probably used by the Soviets suggests that in 1979 the USSR will spend nearly 5 billion rubles[a] for military aircraft maintenance. This amount includes all direct and indirect expenses associated with maintaining the aircraft in the Soviet order of battle except expenses for uniformed personnel and fuels and lubricants (POL). Of all the Soviets' maintenance requirements, military aircraft maintenance appears to carry the highest price tag. It amounts to between 7 and 8 percent of the Soviet Union's likely defense spending in 1979.

Our estimates indicate that the annual cost of military aircraft maintenance has nearly doubled since 1969—rising at an average rate of over 5 percent annually (see figure 2). This rapid increase has resulted from a steady growth in the number of aircraft in the Soviet inventory and their technical complexity. We expect this trend to continue over the next five years.

Estimated Costs of Soviet Military Aircraft Maintenance, 1969-79, in Rubles Figure 2



The trend depicted has been smoothed.

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Comparison With US Costs. Another way of looking at the annual Soviet military aircraft maintenance bill is to translate it into dollar costs: what it might cost the US Department of Defense to maintain the Soviet air inventory as the Soviets do. Converting our approximated Soviet CERs into 1978 dollar terms by use of composite ruble-dollar ratios, we estimate that Soviet military aircraft maintenance will require the equivalent of 6-7 billion dollars in 1979—about 3 billion dollars more than it required in 1969.

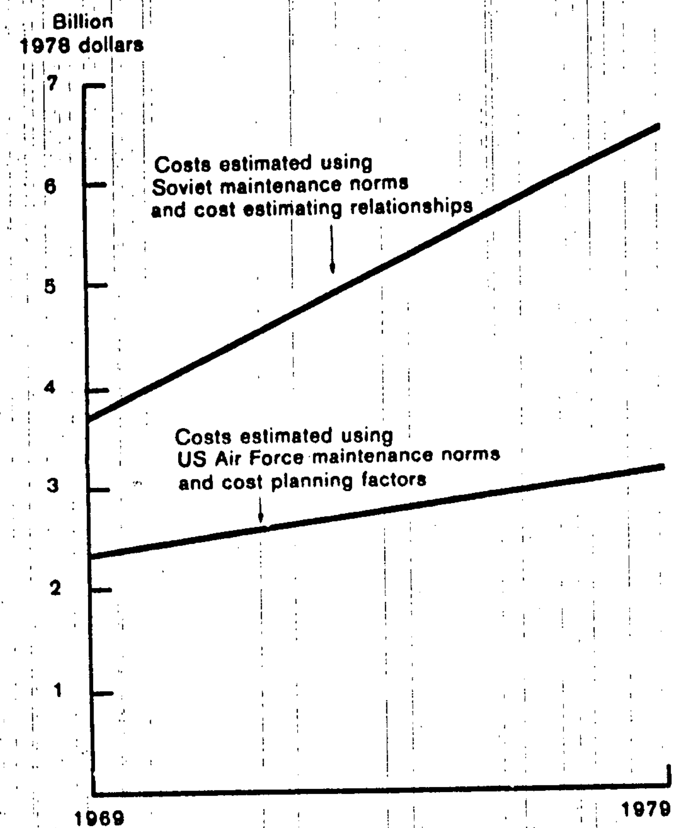
This dollar estimate enabled us to compare the maintenance norms and procedures of the Soviet armed forces with those of the US armed forces in terms of the cost implications of each. To do so, we reestimated the cost of maintaining the Soviet air inventory from 1969 through 1979, using—instead of our approximated Soviet CERs—USAF maintenance cost planning factors for comparable US aircraft, adjusted to reflect the low Soviet operating rates.[b]

This comparison is shown in figure 3. The lower line indicates our estimate of the Soviets' military aircraft maintenance costs if their fleet were maintained

[a] Expressed in constant 1970 prices.

[b] Because the two countries are maintaining different things—the US military aircraft inventory is markedly different from the Soviet inventory in composition, size, and technical characteristics—a simple comparison of their maintenance costs would be misleading.

Estimated Costs of Soviet Military Aircraft Maintenance, 1969-79, in Equivalent 1978 US Dollars Figure 3



The trends depicted have been smoothed.

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according to the USAF maintenance philosophy and practices. The upper line indicates the trend we derived by applying Soviet CERs. A comparison done in dollar cost terms must be treated with caution because several technical considerations may tend to exaggerate the cost differences.[10] The comparison, nevertheless, highlights the relative costliness of the Soviet maintenance system.

As estimated by USAF cost planning factors, Soviet military aircraft maintenance costs grow from a little over 2 billion dollars in 1969 to more than 3 billion dollars by 1979—an average annual increase of 3 to 4 percent. As estimated by our Soviet CERs, the average annual rate of growth is 6 percent—nearly double that implied by the US cost estimators. The Soviet CERs also provide a cost series that is, on the average, 70 to 80 percent higher in level than that derived by the US planning factors.

Reasons for Cost Differences. The more costly nature of the Soviet military aircraft maintenance system is best explained by the extremely conservative Soviet maintenance norms and the short service lives associated with the Soviet airframes and engines. Soviet military aircraft receive more major overhauls in a much shorter time than do their USAF counterparts. In addition, Soviet capital repair practices usually dictate a more extensive and, therefore, more costly overhaul than do US practices. These considerations more than offset savings in maintenance costs which might accrue to the Soviets because of their low annual operating rates, their assembly-line approach to overhaul, and the general ruggedness and simplicity of their equipment.

The Soviet maintenance system also contains hidden costs that are not directly captured in our estimates of annual maintenance expense. The Soviet emphasis on frequent replacement of components and factory overhauls requires that air regiments have large stocks of readily available spare aircraft and replacement parts. This raises not only the annual level of required

[10] For example, the internal price structures of the US and the USSR are different; the US cost planning factors we use were developed for specific aircraft models, whereas the Soviet CERs are more general; and the US cost planning factors may include fewer overhead items.

investment in new aircraft but also the overhead costs of holding the inventory of spares. In addition, the Soviet norms specify what often amounts to redundant maintenance. Although this practice does seem to minimize serious premature failures, too frequent disassembly and maintenance of otherwise serviceable components can weaken them and can increase the risk of foreign object damage.

Outlook

There are no indications that Soviet military leaders are dissatisfied with their aircraft maintenance system. Its guiding philosophy and structure represent a distillation of their World War II experience and an adaptation to their clear perception of the realities of the Soviet economy and armed forces organization. The system is consistent with the Soviet maintenance philosophy for most other major equipment and reflects the view that any major conflict would probably be brief but intense. In short, the Soviets are comfortable with the system and find that it works well in peacetime.

Consequently, we expect the Soviets to continue to modify their military aircraft maintenance system only incrementally. They appear to be contemplating two of these minor alterations, probably as a response to the increasing mechanical and electronic complexity of military aircraft. One is a slight loosening of the strict specialization of maintenance personnel; they are beginning to emphasize the cross-training of technicians in at least two separate tasks. The other change is an increase in the amount and sophistication of test and repair equipment located in regimental maintenance components. We believe that the system will accommodate both changes slowly and without special difficulty.

Although the Soviet military aircraft maintenance system would be extremely expensive to duplicate in the United States, it is probably quite efficient by Soviet standards. It provides an unusually high degree of materiel readiness despite the constraints imposed by the Soviet economy. The centralization and rear orientation of the system create important economies of scale by avoiding unnecessary duplication of specialized equipment and skilled personnel, both of which are scarce resources in the Soviet Union. In several ways—the emphasis on conservative maintenance norms, the assembly-line handling of major repair tasks, and the use of large inventories of aircraft and spare components to offset limited ability at the unit level for complex repair work—the system capitalizes on the production capability of the Soviet aviation industry while minimizing the impact of quality-control problems. Finally, the highly structured nature of the system is well adapted to the stringent requirements of Soviet military and economic planning. Accordingly, we believe it unlikely that the Soviets could achieve their defense objectives for aircraft at an appreciably lower cost.

It is impossible to predict whether the system would function successfully in a conflict with either NATO or Chinese forces. We believe, however, that it would prove adequate—if the fighting followed the short, intense scenarios anticipated by the Soviets. The Soviets are probably aware that, during actual hostilities, maintenance norms could be greatly relaxed and that, at least initially, the maintenance pipelines from air regiments to overhaul plants could be reversed, with many aircraft and engines en route to the overhaul plant being redirected back to line units.

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Appendix A

Costing Soviet Military Aircraft Maintenance

Methodological Approach

Special problems are involved in estimating the annual cost of maintaining a military aircraft in accord with the Soviet system described in the text. The Soviet air forces are closemouthed about their operating costs and budget, and their maintenance philosophy, operating practices, aircraft inventory, and maintenance organization differ enough from those of the US or NATO armed forces to make Western analogues of limited value.

We know, however, from analysis of Soviet military maintenance practices for major equipment other than aircraft that there are strong parallels between military and civilian procedures and accounting methods. The data further suggest that the economic structure of the military aircraft maintenance system in the Soviet Union is similar to that of civil aviation, and that fundamental cost-estimating relationships (CERs) valid in the civilian sector may also hold for the military. Consequently, we believe that the kinds of operating cost planning factors used by civil aviation—which we know—are also used by the Soviet air forces.

Our methodological approach to estimating the annual cost of maintenance for Soviet military aircraft is to use Soviet civil aviation analogues—adjusted to reflect military operating rates and equipment—to approximate the life-cycle cost planning factors probably employed by the armed forces. We derived the civilian planning factors primarily from data and formulas available in texts and handbooks on the economics of Soviet aviation and have checked them against the limited amount of economic intelligence available on Soviet military aircraft maintenance. This approach involves translating the CERs used by civilian planners, in their estimates of amortization, routine repair, and technical servicing costs, into similar equations that military planners might use. (

This approach has an advantage over methodologies based on Western analogues: it mirrors the way in which the Soviet military probably estimates its own aircraft maintenance costs and should yield estimates that reflect Soviet equipment characteristics, operating rates, and maintenance practices.

Assumptions

Although the military, according to Soviet financial definitions, is in the "nonproductive" sector of the economy, we believe its cost structure for aircraft maintenance to be similar to that of civil aviation enterprises. Accordingly its method of planning and accounting for maintenance costs should also be like that of civil aviation.

Both direct and inferential evidence supports this assumption:

- Military and civil aviation have virtually the same maintenance requirements and practices in the USSR. Their maintenance organizations have parallel structures and a common maintenance philosophy. Only the operating rates, times before overhaul (TBOs), and service lives appear to differ, and then mainly as functions of equipment differences.
- Military and civil aviation often share airfield and overhaul facilities.
- Many military aircraft models and engines (particularly in the transport category) are identical to those used by civil aviation.
- The Soviet military reports its operating costs for individual aircraft in the same fashion as does civil aviation. These costs are of similar orders of magnitude and are the same for like-model aircraft.

- In cost planning for other areas of operations and maintenance—vehicles, land arms, and POL—the military uses an approach nearly identical to that of civilian enterprises.
- Sales of Soviet military aircraft to other countries include recommendations for maintenance planning that are similar to those used by the Soviets for nonmilitary aircraft.
- The Soviets, whether by intent or by bureaucratic inertia, strongly favor standardization of equipment and procedures throughout their economy. Our research in other fields strongly indicates that military and civilian planners are usually guided by a common set of norms, especially for maintenance procedures and accounting practices.

Against our assumption it can be argued that the military and civilian aircraft fleets differ significantly. A large portion of the military fleet—fighters and bombers particularly—have missions and designs that are purely military, have weapons, and have more sophisticated avionics than civil aircraft. Although these are valid considerations, we believe that the manufacturing cost basis of the Soviet planning equations adequately reflects such differences because aircraft cost reflects technical complexity.

Two limitations of our methodology must be noted. First, it calculates life-cycle costs and therefore is not necessarily a good approximator of the actual servicing costs of a given aircraft in a given year. Second, it yields budget planning costs rather than historical costs; it will, therefore, tend to overlook temporary problems or deviations from trends and will indicate aggregate maintenance costs better than the costs for a particular aircraft model or a particular aspect of military aviation.

Cost Categories

Soviet economists and aviation authorities identify six categories of aircraft operating expense:

- Fuels and lubricants.
- Amortization (that is, depreciation) of aircraft and engines.
- Routine repair and technical servicing of aircraft and engines.
- Wages of personnel.
- Social security deductions.
- Airfield operations.

Two of these items are relevant for estimating the cost of military aircraft maintenance. These are amortization and routine repair and technical servicing.

The other cost categories—fuels and lubricants, wages, social security deductions, and airfield operations—are less relevant to maintenance expense because they deal predominantly with operational, as opposed to repair, items. In addition, these constitute areas which, for intelligence purposes, require separate cost estimates.

Amortization

The Soviets define amortization in a manner quite different from that normally used by Western economists and accountants. In Soviet finance, the term refers to the initial cost (or wholesale valuation when new) of an item of fixed productive capital plus the cumulative cost of major overhauls performed during its service life and minus its salvage value at retirement. It is usually expressed through a "straight line" calculation on an hourly or yearly basis.

The notion of including the cost of capital (and, sometimes, medium) repair as a component of amortization of capital equipment follows directly from Marxian and Soviet economic theory regarding fixed productive capital. According to this theory, the value of working capital stock is gradually transferred in discrete, homogeneous units to the final product or output during the production process. Working capital stock can regain some of this "lost value," however, through periodic overhauls, which give it a longer service life and, consequently, greater productivity. Thus, when Soviet planners figure the depreciation of an item of fixed productive capital, they lump together its initial wholesale price and its life-cycle cost of capital and medium repair.

A civilian enterprise in the Soviet economy calculates amortization costs on an annual basis for all equipment in its capital stock [11] and deposits in the State Bank payments equal to those costs. Cost planners base their calculations on official tables and norms for service lives and on amortization rates published in professional handbooks. The enterprise will later use a portion of the fund created by these payments to finance overhauls, as they become needed, and the remainder to purchase new items of replacement capital equipment. This process constitutes the "reproduction" or "renovation" of the fixed capital of the enterprise. The amortization payments made on a given item should reflect the lifetime cost of overhauling and eventually replacing it. If they do not, the enterprise will be in financial trouble with both its current accounts and its five-year plan.

The portion of amortization of an aircraft devoted to overhaul includes all costs allocable to capital repair.[12] Because capital repair of aircraft is performed at the factory or a special repair plant, overhaul charges include the costs of replacement parts, labor, shop materials, transportation, and plant overhead.

Routine Repair and Technical Servicing

The category of routine repair and technical servicing for an aircraft covers the costs of current repair, technical servicing, inspection, and maintenance up through medium repair—in other words, all maintenance services except capital repair. Expenses include the cost of replacement parts, special tools and testing instrumentation, and maintenance materials. These costs are usually incurred at the airfield rather than at a repair plant.

The Soviets usually do not plan routine repair and technical servicing costs on a per-aircraft basis. Moreover, because such work generally is performed at the airfield rather than at separate repair enterprises, the costs of personnel and of operating the facilities are not included in this category. Thus, the cost of routine repair and technical servicing covers only direct, material expense, figured as an average for the aircraft fleet.

Derivation of the Estimating Model

Symbols

The aircraft maintenance cost estimating model employs a number of symbols to represent different variables. For convenience, the definitions of these symbols will be grouped into three categories: exogenous variables (values that are derived from data and analysis outside of the model and may, therefore, be taken as given), endogenous variables (values from the data and equations of the model), and parameters (constant values given by the Soviets to define certain fundamental cost relationships).

The symbols are as follows:

Exogenously Derived Variables

P denotes the manufacturer's price (wholesale price to the military) of an aircraft or engine. This price can be given in rubles or in equivalent dollars.

L denotes the service life of an aircraft or engine, given in operating hours or years. An item is written off for salvage value at the expiration of its service life.

R denotes the *resurs* or TBO of an aircraft or engine, always given in operating hours or years of service. When an item reaches the end of its *resurs*, it is shipped to a plant for capital repair.

E denotes the number of engine beds on an aircraft—thus the number of engines that will have to be maintained.

T denotes the annual flying time of a military aircraft, given in hours. It includes all time spent in flight, whether productive (mission-related) or nonproductive (associated with maintenance, testing, or familiarization).

[11] There are strong indications that the military also amortizes at least some of its capital stock—including aircraft and other weapon systems—in peacetime.

[12] For most items other than aircraft—vehicles and engineering equipment, for example—overhaul is usually defined to include medium repair. The general procedure for calculating amortization is otherwise identical.

Endogenously Derived Variables

A denotes the periodic or the lifetime amortization (or amortization rate) of an aircraft or engine; it can be given in rubles or in equivalent dollars.

N denotes the number of capital repairs performed on an aircraft or engine during its service life.

O denotes the annual operating rate of an aircraft or engine, given in hours.

C denotes the periodic or the lifetime cost of one type of maintenance (either overhaul or routine repair and technical servicing) for an aircraft or engine, given in rubles or in equivalent dollars.

TC denotes the total cost—either periodic or lifetime—of all maintenance (that is, both routine and capital repair) performed on an aircraft and its engine(s), given in rubles or in equivalent dollars.

Parameters

k denotes the factor used by the Soviets to determine the cost of a single capital repair: 0.3 for engines, 0.25 for 2- to 5-ton aircraft, 0.165 for 5- to 10-ton aircraft, 0.135 for 10- to 30-ton aircraft, and 0.115 for aircraft of more than 30 tons.

m denotes the Soviets' factor for routine repair and technical servicing, equal to 0.25 (on the average) for aircraft and engines.

o denotes the Soviets' factor for operation of engines on the ground during servicing, equal to 1.02 for airplanes and 1.03 for helicopters.

s denotes the factor—0.95—used by the Soviets to adjust the manufacturer's cost of an aircraft or engine to reflect subtraction of salvage value (about 5 percent of initial cost).

In addition to these symbols, superscripts and subscripts are used. The superscripts indicate the time interval in which or for which a value is expressed. The subscripts indicate which part of the maintenance program a value refers to.

Superscripts

h denotes that the value is given in hours or per hour.

l denotes an aggregate, lifetime value.

y denotes that the value is given in years or per year. (s)

Subscripts

a denotes that the value is given for an aircraft (airframe, avionics, and weaponry), exclusive of engine(s).

e denotes that the value is given for an engine.

k denotes that the value is given for capital repair (overhaul).

m denotes that the value is for routine repair and technical servicing.

Capital Repair

The Soviets estimate the cost of a capital repair to be a fixed proportion of the wholesale price of the item being repaired. For an aircraft or an engine, the cost of one capital repair can be expressed in general terms as kP. If the item is overhauled N times during its service life, then the life-cycle cost of capital repair is

$$C_k^l = NkP$$

The value for k is given in handbooks on aviation economics. The value for N can be computed as

$$N = \frac{L}{R} - 1$$

L and R are set by the manufacturer. We know that civil aircraft usually undergo capital repair three to five times and their engines once or twice. Military aircraft usually have shorter service lives than civil aircraft and, consequently, fewer required overhauls.

The Soviets define the lifetime amortization of an aircraft or engine as the sum of its initial cost (less salvage value at the end of its service life) and the lifetime cost of capital repairs performed on it. Therefore,

$$A^l = sP + NkP$$

Because payments are made annually, the yearly amortization rate for an aircraft or engine can be expressed as

$$A^y = \frac{sP + NkP}{L^y}$$

If the service life is not specified in years, it can be found by dividing the service life in hours by the annual operating rate, or

$$L^y = \frac{L^h}{O}$$

For aircraft, the operating rate is equal to the annual flying time. For engines, however, the operative rate also includes on-ground running during maintenance; the adjustment is

$$O_e = oT$$

In their cost calculations, the Soviets make an adjustment to include nonproductive flying hours (training and the like). Our independent estimates of T include these, and no such adjustment need be made here.

Thus, the annual portion of the amortization payment for an aircraft or an engine devoted to capital repair is given as

$$C_k^y = \frac{NkP}{L^y}$$

Routine Repair and Technical Service

The cost of routine repair and technical servicing is not part of the amortization rate. The Soviets estimate this cost for engines and aircraft by a very intricate calculation, expressing it as a function of annual operating rate, technical complexity of work involved, types of personnel performing the work, and wage rates of those personnel. Unfortunately, we lack access to the handbooks that provide the formulas and factors for such a calculation.

All is not lost, however, because for planning purposes the Soviets have a second way of expressing the annual and hourly cost of routine repair and technical servicing: as a function of other aviation costs. There are probably two reasons for the simpler method: first, the overcomplex nature of the calculation via the complete formula and, second, the uncertainties involved in predicting the kinds and quantity of current repair that will be required. In addition, Soviet accountants appear to prefer to monitor these costs on a fleet basis rather than an item basis, perhaps because of the difficulties involved in fully allocating all expenditures to individual items.

In any case, we can determine from Soviet texts on aviation economics that during the 1960s and 1970s routine repair and technical servicing costs have been equal to a slightly declining fraction (currently about 25 percent) of annual amortization costs. Moreover, tables of historical data for certain aircraft models do exist. Comparison of the relation of routine repair and technical servicing costs to amortization cost for a selected group of aircraft models used by both civil aviation and the military indicates that the national figures seem to be accurate estimates for individual aircraft.

Given all this, we can express the annual cost of routine repair and technical servicing for an aircraft or engine as a function of the relevant annual amortization rate. Thus,

$$C_m^y = mA^y$$

or

$$C_m^y = m\left(\frac{sP + NkP}{L^y}\right)$$

Total Maintenance Costs

To this point we have followed the conventions of Soviet accounting in keeping separate the costs for an aircraft and its engine(s). In practice, however, the annual cost of maintaining the complete system is the sum of the cost of maintaining the aircraft and that of maintaining its engine(s). That is,

$$TC^y = (C^y_{ka} + C^y_{ma}) + E(C^y_{ke} + C^y_{mc})$$

where E is the number of installed engines (equal to engine beds) on the aircraft. This can be expressed in more complex form as

$$TC^y = \left(\frac{N_a k_a P_a}{L^y_a} + \frac{m(sP_a + N_a k_a P_a)}{L^y_a}\right) + E\left(\frac{N_c k_c P_c}{L^y_c} + \frac{m(sP + N_c k_c P_c)}{L^y_c}\right)$$ [redacted]

We have not included the cost of replacement engines within the expression for total aircraft maintenance. Both the Soviet and the US military cost planners consider this to be an investment item, not a maintenance expense. Although a typical Soviet aircraft may require five or more engines for each of its engine beds over the duration of its service life, only one engine per engine bed will be maintained at any one time, and our cost estimating equations reflect this. [redacted]

Adapting the Model to Military Aviation

The above model is valid for aircraft in Soviet civil aviation, but it is written in terms that can also be applied to armed forces aircraft. Such an application requires appropriate values for the exogenous variables *P, L, R, E*, and *T*. These variables can be valued only through independent intelligence analysis. [redacted]

The value for *P*, the manufacturer's price of the aircraft or engine, can be chosen in either of two ways: the average unit price for the year of production or the cumulative average unit price over the entire production run. The Soviets themselves opt for the former, at least in theory, thus allowing economies of scale and learning to influence maintenance costs over time. This seems to be a realistic procedure. [redacted]

The Soviet value for *P* is in rubles, but for purposes of sizing Soviet expenditures relative to those of the United States, we can use an equivalent dollar cost. If the ruble-dollar ratio between product costs on both sides is properly constructed, use of a dollar value for *P* in the maintenance CERs should yield a cost estimate that approximately reflects the expense which the US armed forces would incur if they maintained the aircraft and engine(s) according to Soviet practice and specifications, but in this country. [redacted]

The service life (*L*) and TBO (*R*) of an engine or aircraft must be determined for each aircraft model on the basis [redacted] Unfortunately, our data are spotty in terms of both models and years, and we must make a number of analytical judgments in assigning service lives and TBOs to Soviet military aircraft and engines. In general our research indicates that military aircraft have shorter service lives than civil aircraft and that fewer capital repairs—at shorter intervals—are performed. This is clearly an area requiring additional research. (Appendix B presents our estimates of service lives, TBOs, and operating rates for military aircraft types.) [redacted]

The number of installed engines (*E*) is easily determined from technical analysis. It may be considered completely accurate. [redacted]

A more serious consideration affecting the cost of maintenance of a given aircraft is whether spare engines (over and above those installed) should be counted in the estimating equations. We believe they should not, because they receive only limited maintenance and because the Soviets would not begin to amortize a spare for capital repair until it actually came into service. [redacted]

The annual flying time (*T*) must be calculated from data given [redacted] In general, to calculate *T* for a given aircraft model in a given role we divide the total flying time logged by a military air unit by the total aircraft inventory credited to it. Consequently, *T* should account for all operating hours except those relating to servicing. [redacted]

We assume that the cost estimating model and the associated parameters valid for Soviet civil aviation are also valid for the military. We have examined them closely for intuitive reasonableness and for comparability—with known practices and factors in other areas of Soviet maintenance cost estimation and with US practices and factors. We have found no notable inconsistencies and no indication that the use of the civilian-derived model yields results that are qualitatively or quantitatively out of line with other data.[13]

We feel that the weakest points in this estimating system are not the model and its parameters, but rather the values for the exogenous variables which must be supplied from other analysis.

Cost Estimating Relationships

The algebraic model presented above can be used to construct a set of cost estimating relationships for the maintenance of the various types and models of Soviet military aircraft. Substituting the values for the fixed parameters into the equation on page 16, and reducing, the following generalized cost estimating relationship can be written:

$$TC^y = \left(\frac{1.25N_a k_a + 0.2375}{L_a^y}\right)P_a + \left(\frac{0.375N_e + 0.2375}{L_e^y}\right)EP_e$$

The first term in the expression calculates maintenance costs for the airframe, avionics, and fixed weaponry, while the second does the same for the engine(s). Although the CER is written to estimate annual costs, it can be used to compute hourly expenses if the appropriate substitutions are made. Values for P, L, E, and N are known or easily derived for the particular model aircraft whose maintenance costs are to be estimated. The value for the parameter k for airframes is given by weight class.

[13] In fact, we have been able to duplicate reported military operating costs for specific aircraft (including fighters) with estimates from our CERs.

For some Soviet military aircraft, our only data are the price of the aircraft and the number of its engines. In this case we can use a generalized version of the CER, with typical instead of specific values for N and L. (This "shorthand" form of the calculation may sometimes be useful even when we do possess a complete set of values.)

Thus, if an airframe is assumed to be overhauled four times and have a life of 15 years and an engine to be overhauled twice and have a life of five years,[14] the CER may be rewritten as

$$TC^y = (0.333k_a + 0.0158)P_a + 0.1975EP_e$$

In an even more generalized form, using an average value for the capital repair factor for airframes, an equation valid as a crude estimator of maintenance costs for any military aircraft may be written as

$$TC^y = 0.07125P_a + 0.1975EP_e$$

[14] These values are hypothetical and do not necessarily represent our best estimates.

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Appendix B

Operating and Maintenance Norms for Soviet Military Aircraft [1]

Aircraft Type	Force or Service	Annual Flying Time (Hours)	Airframe				Engine			
			Time Before Overhaul (TBO)		Service Life		Time Before Overhaul		Service Life	
			Hours	Years	Hours	Years	Hours	Years	Hours	Years
Fighter/interceptor, fighter-bomber, and medium-range bomber	Frontal (tactical) Aviation, Air Defense Forces (PVO), and Navy	100 in Frontal Aviation, 150 in PVO and Navy	400	6-7	1,600-2,000	12-15	250	3-4	500-700	6-7
Intermediate-range bomber	Long Range Aviation and Navy	100	400	6-7	1,600-2,000	12-15	250	3-4	500-700	6-7
Long-range bomber (jet)	Long Range Aviation and Navy	120	5,000	6-7	15,000	15-20	2,000	3-4	6,000	6-10
Long-range bomber (turboprop)	Long Range Aviation and Navy	220	5,000	6-7	15,000	15-20	2,000	3-4	6,000	6-10
Antisubmarine warfare/seaplane	Navy	220	5,000	6-7	15,000	15-20	2,000	3-4	6,000	6-10
Reconnaissance or early warning aircraft	Frontal Aviation and Air Defense Forces	100 in Frontal Aviation, 220 in PVO	Norms are same as for like-model aircraft in other roles.							
Trainer	All [2]	160	Norms are same as for combat or transport variant.							
Fixed-wing transport	All	600+	5,000	6-7	15,000	15-20	2,000	3-4	6,000	6-10
Rotary-wing aircraft (transport)	All	220	2,000	6-7	8,000	15	600-1,000	3-4	2,000	7-9
Rotary-wing aircraft (combat/assault)	All	150-220	2,000	6-7	8,000	15	600-1,000	3-4	2,000	7-9

[1] Estimated values are approximated for typical aircraft of a given type or role. Specific models may have TBOs and service lives that differ from these estimates.
[2] The category "all" includes Military Transport Aviation, Ground Forces, and Strategic Rocket Forces, in addition to the elements mentioned above.