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THE ECONOMICS OF SOVIET MILITARY AIRCRAFT MAINTENANCE (U)

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THE ECONOMICS
OF
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PREFACE

This paper presents an analysis of the economics of Soviet military aircraft maintenance. It outlines the aviation maintenance system of the Soviet armed forces and sets forth a simple model, based on our approximation of Soviet cost-planning factors, for estimating the annual costs of military aircraft maintenance. [redacted]

Our analysis is based mainly on data from 1970 through 1978, the period for which information is best. In focusing on such a narrow time span, however, the reader should not infer that the Soviet aircraft maintenance system is static. Though the Soviet military adopts new practices very slowly, technological changes in the aviation industry coupled with lessons in aircraft operations and maintenance learned by the military and civil enterprises have led to modifications in maintenance requirements and procedures over the past two decades. [redacted]

We have analyzed the military aircraft maintenance system from the viewpoint of a Soviet planner and economist in order to avoid problems arising from methods which impute US Air Force maintenance cost structures and practices to the Soviets. Such problems include:

--Ignoring or blurring many key features of the Soviet maintenance system which distinguish it from the US system.

This working paper was prepared in the [redacted] Office of Strategic Research. Comments and queries are welcome, [redacted]

--Using cost-estimating relationships (CERs) that are invalid because they have been derived for a "population" (the US Air Force air order of battle) quite different in size, composition, organization, and operating rates from the Soviet population to which they would be applied.

--Incorporating many errors and uncertainties in the US data into the Soviet cost estimates. [redacted]

This analysis draws primarily on four types of sources: (1) open-source Soviet treatises on the economics of air transport and civil aviation; (2) [redacted]

The analysis in this working paper is based on information available through 1 January 1979. [redacted]

[redacted]

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Maintenance 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 conservative scheduling of maintenance.

Preventive Maintenance. Emphasis on frequent technical servicing and preventive maintenance is attractive to the Soviets for several reasons. It is, 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 is, in part, because of quality control problems in their manufacture and the greater use of mechanical--rather than automated and solid state--assemblies and controls. The Soviet military also does not appear to feel the manpower constraints experienced by most Western armed forces. With a large body of conscripts to be kept occupied, availability of "busy work" is an advantage and a good 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 repairs at large, specialized factory-like plants. For the Soviet military, however, the practice also makes sense because replacement of parts which are defective or have reached the ends of their service lives requires less discretionary judgment--and, usually, technical skill--on the part of regimental maintenance personnel than trying to fix them. This is an advantage for a largely conscripted force with short terms of service and limited training opportunities. Replacement rather than repair also helps to insure day-to-day readiness of equipment and makes for easier long-range planning of maintenance requirements.

Rebuilding. The Soviet concept of periodically rebuilding aircraft and other items of capital equipment during overhauls is almost purely a fixture of Marxist-Leninist economics. Unlike the US, the Soviets view capital repair as a re-manufacture of the item in question to restore its original value.

Soviet military planners see the capital repair program as a means of making sure that all equipment will be combat ready. Soviet overhaul practices run counter to the US philosophy of not tampering with things that work properly and restricting overhaul to components that actually require it. The costly Soviet practice would not be tolerated in most Western economies, but seems to pose few problems--as yet--for the USSR's economy. From a US military point of view, mandatory, periodic rebuilding of an aircraft would be regarded as inefficient, financially wasteful, and probably dangerous.

Specialization. The Soviet armed forces place great stress on specialization of tasks and on narrowly focused technical proficiency of maintenance personnel. Consequently, maintenance and overhaul units are organized into separate shops and task groups according to specialty, and maintenance technicians are encouraged by their commanders, the military press, and the Party to become masters of their jobs. In addition, maintenance manuals for Soviet aircraft outline in minute detail what, when, and how all maintenance and servicing procedures are to be performed. Maintenance schedules are rigidly followed and 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 returned either to a repair plant or the factory for servicing and overhaul. Factory technicians are sometimes brought into the regiment or repair plant to assist with particularly complex or sensitive maintenance tasks, especially on new aircraft models. The cumulative thrust of this stress on specialization is to simplify the maintenance process and allow it to be more effectively carried out by a military staffed mainly by conscripts.

Conservative Scheduling. Soviet military aircraft maintenance schedules are set very conservatively. Comparison of times before overhaul (TBOs) and service lives for military aircraft with those of like model civilian aircraft indicates that the Soviet armed forces employ shorter and more rigidly enforced maintenance intervals. In part, this may be an attempt to tailor maintenance frequency to the high sortie rates and more rigorous flight profiles of the military. In any event, the Soviets seldom seem to find it necessary to replace components prior to their scheduled times for inspection or removal.* 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.

Maintenance 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 to those for vechicles, land arms, and ships.

Routine Repair and Technical Servicing. Routine (or current) 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 prior to the expiration of their service lives or before they reach the time for scheduled overhaul. Routine repair is performed on an "as needed" basis. In contrast, technical servicing refers to the periodic servicing, calibration, and lubrication performed at specified intervals in conjunction with detailed inspections of the aircraft and its main components. Most routine repair is performed during the process of inspection and technical servicing.

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* The Soviet military does experience premature failures, but, because maintenance intervals are so short, these are usually not disabling and often can be corrected during normal, planned maintenance actions.

Overhaul. Medium repair (referred to as srednyy--or, for aircraft, sometimes profilakticheskiyy--remont) involves replacement and subsequent overhaul of a limited number of principal components. It is normally performed in conjunction with the last major inspection conducted at the airfield (though, for civilian aircraft and non-Soviet Warsaw Pact military aircraft, it is often done at a repair plant). Capital repair (referred to as glavnyy--or kapitalnyy--remont) involves a major overhaul and virtual rebuilding of the aircraft and the replacement of all components whose service lives have expired. The major distinctions between medium and capital repair for aircraft lie in the number of maintenance procedures performed and the fact that capital repair is always done at a repair plant or the factory.*

Modernization and Modifications. The Soviet military (like civil aviation enterprises in the USSR) considers modernization and modification to be an integral part of the aircraft maintenance program. During routine maintenance and overhaul, improvements and modifications are made to enhance the performance and maintainability of the aircraft. This process is regarded by the Soviets as critically important for readiness.

Major modifications, however, which significantly alter the performance or mission capabilities of a given aircraft are not considered part of maintenance by the Soviets. Once such alterations were complete, the aircraft would be, generally, redesignated as a different model.

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* For aircraft, this distinction is not drawn as clearly by the Soviets as for other types of capital equipment. In our judgment for most modern aircraft operated in the USSR, medium repair has become merged with current repair and technical servicing, and is performed at the airfield.

Maintenance Norms

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

Both the TBO and the service life are calculated by the Soviets in terms of hours of operation and aircraft age in service. The TBOs and service lives of the main components of a given aircraft model determine when overhauls will be performed, components be exchanged, and, to a lesser extent, major inspections occur. Thus, as TBOs and service lives vary from one Soviet aircraft model to another, so too will the frequency of overhaul. Because the schedule for technical servicing is less dependent on TBOs and service lives, it is more uniform from one aircraft model to the next.

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 initially set extremely low. As the production run for the aircraft lengthens and maintenance histories for various units accumulate, the TBO and service life are gradually lengthened. An increase in the TBO and service-life norms for a given model of aircraft will apply to all units in that model run, irrespective of when they were manufactured but assuming their servicing and overhaul have been kept up-to-date. This last condition insures that the aircraft will have been appropriately modified to reflect component improvements. Otherwise, increased norms could present problems.*

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* 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 a decreasing TBO for a given aircraft. As an aircraft or engine

Although TBO and service-life norms are set on the basis of theoretical testing and actual maintenance experience, they are principally functions of materials, design, and quality control. The Soviets acknowledge 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 usually surpass those of comparable engines from other designers. [redacted]

Quality control appears to be even more important. Soviet aircraft manufacturers have found that the TBOs and service lives for their products--which are usually quite low by Western standards--can often be doubled or tripled simply by upgrading workmanship and quality inspection. Often an aircraft manufacturer will offer two versions of the same product, the difference being in the quality control exercised in its manufacture. The version with the better workmanship has an increased service life and a concomitantly higher price. [redacted]

Manufacturers have a stake in keeping 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 also, in the case of an aircraft produced for the military, be subject to a stiff fine. [redacted]

On the other hand, the Soviets are well aware that short TBOs and service lives lead to low aircraft productivity and, for the military, diminished readiness. Since the early 1960s, they have made a concerted effort to lengthen maintenance and replacement intervals, primarily through the use of more durable materials and the application of better quality standards. [redacted]

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progresses through its service life, the interval between overhauls will slowly become shorter, reflecting an anticipation of normal mechanical wear and metal fatigue. The Soviets appear to allow for this by keeping the resource of an item low and also by incorporating a discretionary range (usually ± 5-10 percent) in it. [redacted]

Planning. In planning for technical servicing and overhaul, the Soviets differentiate between the aircraft itself--which includes the airframe, avionics, and fixed weaponry--and its engine(s). This distinction is made because, in accord with Marxian economics, both the aircraft and its engines are classed as discrete items of productive capital. Consequently, for a given fixed or rotary wing aircraft, two separate master maintenance schedules exist: one for the engine(s) and one for everything else.* These two schedules are not always fully integrated, a factor which probably results in some unnecessary downtime--though there is little indication that the Soviets see it as a problem.** [redacted]

Apart from the peculiarities of Soviet economics, there is a practical reason for differentiating between engine and aircraft maintenance schedules: the disparity in service lives and overhaul frequencies between the two. Normally, the Soviets figure the service life of an engine to be 25-50 percent of that of the airframe. In addition, an airframe may have as many as five or more allowable overhauls, but a Soviet engine seldom has more than two or three at most. What this means is that a Soviet aircraft that lasts to the end of its service life (and most probably do) will have required five or more 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 flight or operating*** hours. Because

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* The Soviets also use discrete sub-schedules for major components such as the electrical system and the radar, but these are generally meshed into the master schedules for the airframe. [redacted]

** 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, as, for example, is the case with the MiG-21 (Fishbed) whose engine is integrally mounted with the fuselage, it appears that a conscious attempt has been made to mesh both maintenance schedules. [redacted]

*** For a high performance fighter, the norms are set in regular operating hours and in afterburner hours. [redacted] deterioration and metal fatigue are aggravated by age, they are also set in calendar years. But, for most aircraft, annual operating hours are the crucial measure for determining when various types of maintenance are performed. In the case of the airframe, operating rate equates to hours spent in flight. For an engine, operating rate includes not only flying time but also time spent running on the ground (whether in warm-up or servicing). [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 equally important. In recent years, for example, the US Air Force has begun to adapt to this problem by setting forth maintenance schedules geared to these other measurements. The Soviet military (along with civil aviation) continues to cling to the use of operating hours as the determinant of the maintenance schedule: they are an easy measurement to make and use in planning calculations; they are not computed--by the Soviets--independently of sortie rates and therefore <u>do</u> partially reflect number of takeoffs for a particular aircraft in a given role; and existing maintenance schedules (in operating hours) are already drawn conservatively enough to insure that aircraft usually are serviced before mechanical trouble develops. [redacted]

Military Maintenance Organization

<u>Air Regiments</u>. For the Soviet military, the air regiment constitutes the basic fighting and maintenance unit. 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. One echelon supports another. Maintenance 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 <u>TECh</u>. The <u>TECh</u> (or squadron technical unit, as it is sometimes called) 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 repair of engines, armament, safety equipment, electrical equipment, radios and radar, and, where appropriate, photo-reconnaissance equipment. The <u>TECh</u> is responsible for performing major inspections, medium repair, and current repair that cannot be done at lower echelons. In the event that an aircraft cannot be brought to <u>TECh</u> facilities, the <u>TECh</u> can organize portions of its crews into a mobile maintenance group, the <u>PARM</u>, transported in vans.

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

The flights are, in turn, composed of flying teams and servicing teams. Each servicing team, consisting of an officer of equal rank to that of the flight team pilot* (usually a lieutenant or senior lieutenant) and two technicians, is responsible for the pre-flight and post-flight inspections of the aircraft in the regimental inventory to which it is assigned.

<u>Air Technical Battalions</u>. Military airfields are operated by air technical battalions, which perform separate functions from those of the regimental maintenance organization. The air technical battalion (or <u>obato</u>) is

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* Unlike the situation in the US Air Force--where virtually all hands-on maintenance procedures are supervised and performed by enlisted personnel--Soviet commissioned and warrant officers often work alongside conscript technicians in performing even routine tasks.

organizatonally distinct from the air regiment. The responsibilities of the <u>obato</u> 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 air technical battalion is not involved directly in the maintenance of aircraft, but its work is an essential prerequisite to the proper functioning of the regimental maintenance organization.

<u>Overhaul Plants</u>. 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 also overhauled at civilian-run plants. Similarly, civilian aircraft can be overhauled in military-operated 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--<u>khozraschet</u>--basis. Each Soviet air army has a number of overhaul plants subordinate to it, with each facility specializing in the repair of a particular type of aircraft (e.g., fighters, bombers, transports).

Aside from functioning as capital repair depots, overhaul plants also perform specialized repairs and modifications beyond the capability of air regiment maintenance staffs.

<u>Effectiveness of Military Aircraft Maintenance</u>

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

Servicing and replacement of components in advance of expected failure and at intervals shorter than required by normal wear may seem inefficient but probably does assure 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 simpler.

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 from the use of short-tenured conscripts are compensated for by the organization of the maintenance system, its functional compartmentation, and the routinized, cookbook nature of most maintenance operations. The Soviet practice of having maintenance teams, parallel to flying teams, responsible for particular aircraft appears to be a good way of insuring personal accountability and responsibility for servicing and repair work. Such accountability is necessary because, propaganda aside, maintenance personnel are held in lower esteem than their flying colleagues, and they appear to suffer from a lack of hands-on training prior to assignment to line jobs.

In the event of war, the organization of the Soviet aircraft maintenance system with its many tiers and 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. Though well enough trained and equipped for routine, peacetime tasks, the regimental maintenance organization is probably not adequate for handling the heavy flow of unpredictable but complex repair jobs that might arise during an extended period of warfare. The Soviet dependence on rear support for major air maintenance work--though 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.

COSTS OF SOVIET MILITARY AIRCRAFT MAINTENANCE

Methodological Approach

Estimating the annual cost of maintaining a military aircraft in accord with the Soviet system just described presents special problems. The Soviet Air Forces are closed-mouthed about their operating costs and budget. Their maintenance philosophy, operating practices, aircraft inventory, and maintenance organization are substantially different from those of the US or NATO armed forces. Thus Western analogues are 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 methods of accounting. Moreover, the data suggest that the economic structure of the military aircraft maintenance system in the Soviet Union is similar to that for civil aviation, and that fundamental cost-estimating relationships valid in one sector may also hold for the other. Consequently, we believe that the same kinds of operating cost planning factors used by civil aviation are also used by the Soviet Air Forces--and the civil factors <u>are</u> known.

Our approach, therefore, to estimating the annual cost of maintenance for Soviet military aircraft is to approximate the life-cycle cost planning factors probably employed by the armed forces by using Soviet civil aviation analogues adjusted to reflect military operating rates and equipment. These planning factors are derived primarily from data and formulas available in texts and handbooks on the economics of Soviet aviation--and have been checked against the limited amount of economic intelligence available for Soviet military aircraft maintenance. In large measure, this methodological approach involves translating civil aviation CERs used to estimate amortization, routine repair, and technical servicing costs into similar equations that might be employed by military planners.

Apart from avoiding the disadvantages of approaches based on Western analogues, this methodology has the advantage of mirroring the way in which the Soviet military probably estimates its own air maintenance costs. Additionally, it should yield cost estimates that more fully reflect Soviet equipment characteristics, operating rates, and maintenance practices.

Assumptions

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

There is direct and inferential evidence to support this assumption:

--Aircraft maintenance requirements and practices are virtually the same for both civil and military aviation. Their maintenance organizations have parallel structures and share a common maintenance philosophy. Only operating rates, TBOs, and service lives appear to differ, and then mainly as a function of equipment peculiarities.

--Military and civil aviation often share common 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 in the same fashion for individual aircraft as does civil aviation, and these costs are of similar orders of magnitude and are the same for like model aircraft.

--In other areas of operating and maintenance cost planning (vehicles, land arms, POL), the military uses an approach nearly identical to that of civilian enterprises.

--Analysis of Soviet military aircraft sales to other countries suggests that recommended maintenance planning for these items is similar to that used by the Soviets for non-military aircraft.

--The Soviets, whether by intent or merely bureaucratic inertia, strongly favor standardization of equipment and procedures throughout their economy. Prior research strongly indicates that, especially for maintenance procedures and accounting practices, both military and civilian planners are usually guided by a common set of norms.

It can be argued, however, that a large portion of the military aircraft fleet--fighters and bombers immediately come to mind--is significantly different from anything in the civil fleet: their missions and designs are purely military, and they possess weapons and more sophisticated avionics. Though these are valid considerations, we believe that the manufacturing cost basis of the Soviet planning equations allows for the differences because aircraft cost does reflect relative technical complexity.

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

Cost Categories

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

--Fuels and lubricants.

--Amortization (or, depreciation) of aircraft and engines.

--Routine repair and technical servicing of aircraft and engines.

--Wages of personnel.

--Social security deductions.

--Airfield operations.

For estimating the cost of military aircraft maintenance, two of these items are relevant for our purposes: amortization and routine repair and technical servicing.

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

The notion of including capital (and, sometimes, medium) repair costs as a component of amortization of capital equipment follows directly from Marxian and Soviet economic theory regarding fixed productive capital. According to this theory, during the production process the value of working capital stock is gradually transferred in discrete, homogeneous units to the final product or output. Part of this "lost value," however, can be restored through the process of periodic capital repair and rebuilding, thereby allowing a longer service life and, consequently, greater productivity for the item. Thus, Soviet planners lump the life-cycle cost of overhauling an item of fixed productive capital together with its initial wholesale price in figuring its depreciation.

Civilian enterprises in the Soviet economy calculate amortization costs on an annual basis for all equipment in their capital stock* and deposit payments equal to those calculations in the State Bank. They base their calculations on official tables and norms for service lives and amortization rates published in professional handbooks. A portion of these payments is used to finance capital repair as it becomes needed and the remainder goes to purchase new items of replacement capital equipment. This process constitutes the so-called reproduction, or "renovation," of the fixed capital of the enterprise. As a result, the amortization payments made on a given piece reflect the lifetime cost of overhauling and eventually replacing that item. If they do not, then the affected 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. (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.) 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.

<u>Routine Repair and Technical Servicing</u>. The category of routine repair and technical servicing covers the costs of current repair, technical servicing inspection, and maintenance up through medium repair--in other words, all other maintenance services except capital repair. Expenses in this category include the cost of replacement parts, special tools and testing instrumentation, and maintenance materials. These costs are usually incurred at the airfield

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* There are strong indications that the military also amortizes at least some of its capital stock in peacetime. Whether this is also done for aircraft and other weapons systems, however, is not known for certain.

rather than at a repair plant.

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

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.

Derivation of the Estimating Model

Symbols. As an aid in expressing the aircraft maintenance cost-estimating model and its derivation, a number of symbols need be defined. For convenience, these will be grouped into three categories: exogenous variables (values derived from data and analysis outside of the model and which 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 the shape of certain fundamental cost relationships).

The symbols for the variables of the model are:

Exogenously-Derived

P denotes the manufacturer's price (wholesale price to military FOB factory of origin) of an aircraft or engine. This price can be given in rubles or 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 "resource" or TBO of an aircraft or engine, always given in operating hours or years of service. When an item reaches the end of a TBO interval, it is shipped to a repair plant for overhaul.

E denotes the number of engine beds (or installed engines) on an aircraft.

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

Endogenously-Derived

A denotes the periodic or lifetime amortization or amortization rate of an aircraft or engine, given in rubles or equivalent dollars.

N denotes the number of overhauls 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 lifetime cost of overhaul or routine repair and technical servicing for an aircraft or engine, given in rubles or equivalent dollars.

TC denotes the periodic or lifetime cost of all maintenance performed on an aircraft and its engine(s), given in rubles or equivalent dollars.

Parameters

k denotes the capital repair (overhaul) factor, equal to .3 for engines, .25 for 2-5 ton aircraft, .165 for 5-10 ton aircraft, .135 for 10-30 ton aircraft, and .115 for aircraft over 30 tons.

m denotes the factor for routine repair and technical servicing, equal to .25 (on the average) for aircraft and engines.

o denotes the 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 used to adjust the manufacturer's cost of an aircraft or engine to reflect subtraction of salvage value, equal to .95.

In addition to these symbols, a number of subscripts and superscripts are also used. These are:

Superscripts

h denotes a value given in hours or per hour.

l denotes an aggregate, lifetime value.

y denotes a value given in years or per year.

Subscripts

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

e denotes a value for an engine.

k denotes a value for capital repair (overhaul).

m denotes a value for routine repair and technical servicing.

Using these symbols, we can begin to define the model used by Soviet planners to calculate lifetime costs of aircraft and engine maintenance. From these life-cycle costs, annual costs can be derived easily.

Capital Repair. The Soviets estimate the cost of an overhaul or capital repair to be a fixed proportion of the wholesale price of the item being repaired. For an aircraft (airframe, avionics, and fixed weaponry) or an engine, the cost of an overhaul 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

$$C_k^1 = NkP .$$

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

$$N = (L^h / R) - 1 ,$$

where L and R are set by the manufacturer. We know that the frequency of overhaul is usually 3-5 times for civil aircraft and 1-2 times for their engines. Military service lives are usually shorter than for civil aircraft, and overhaul frequencies less.

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

$$A^1 = sP + NkP ,$$

where s is a factor used to "net out" salvage value (usually about 5 percent of manufacturer's cost for aircraft and engines). Because amortization payments are made annually, the yearly rate for an aircraft or engine can be expressed as

$$A^y = (sp + NkP) / L^y .$$

The service life in years, if not otherwise known, can be found by dividing the service life in hours by the annual operating rate, or

$$L^y = L^h / O .$$

For aircraft, the operating rate is equal to the annual flying time. For engines, however, an adjustment must be made to account for on-ground running during maintenance; thus,

$$O_e = oT .$$

The Soviets also make an adjustment for non-productive flying hours (training and the like), but, because our independent estimates of T include these, no such adjustment need be made here.

It follows directly, therefore, that the annual portion of an amortization payment devoted to capital repair of an aircraft or an engine is given as

$$C^y_k = NkP / L^y .$$

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 direct 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 which provide the formulas and factors for such a calculation.

All, however, is not lost, because for planning purposes the Soviets also express the annual and hourly cost of routine repair and technical servicing as a function of other aviation costs. There are probably two reasons for this: the overly-complex nature of the calculation via formula, and the uncertainties involved in predicting the kinds and quantity of current repair that will be required. In addition, it appears that Soviet accountants prefer to monitor these costs on a fleet rather than 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 over the past twenty years 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

$$C_m^y = m ((sP + NkP) / L^y) .$$

Total Maintenance Costs. Up till now, we have retained, in accord with the conventions of Soviet accounting, the definitional split between 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,

$$TC^y = (C_{ka}^y + C_{ma}^y) + (E (C_{ke}^y + C_{me}^y)) ,$$

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

$$TC^{y} = (N_a k_a P_a / L_a^{y} + m(sP_a + N_a k_a P_a) / L_a^{y}) +$$

$$E(N_e k_e P_e / L_e^{y} + m(sP_e + N_e k_e P_e) / L_e^{y}).$$

Note that we have not included the cost of replacement engines within the expression for total aircraft maintenance. Both the Soviets and the US consider this to be an investment item and, consequently, do not account for it as a maintenance expense. It should be kept in mind, however, that 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, however, will be maintained at any one time, and our cost-estimating equations are written so as to reflect this.

Adapting the Model to Military Aviation

The above model is valid for aircraft in Soviet civil aviation, but we have written it in terms that can also be applied to the military. To use it for armed forces aircraft, values for P, L, R, E, and T must be derived. These variables can be valued only from independent intelligence analysis.

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.

The Soviets, of course, use a value for P in rubles. An equivalent dollar cost, however, can be used for purposes of sizing Soviet expenditures relative to those of the US. If the ruble-dollar ratio between product costs on both sides is properly constructed, use of a dollar value of P in the maintenance CERs should yield a cost estimate that approximately reflects the expense which would be incurred by the US armed forces if they maintained the aircraft and engine(s) according to Soviet practice and specifications but in this country.

The service life (L) and resource (R) of an engine or aircraft must be determined for each aircraft model. The primary sources of data for this are [redacted] and [redacted] maintenance handbooks. Unfortunately, these data are spotty in terms of both model and time coverage. Consequently, a number of analytical judgments must be made in assigning service lives and TBOs to Soviet military aircraft and engines. In general, however, our research indicates that military service lives are usually shorter than those for civil aircraft and that fewer overhauls--but at shorter intervals--are performed. This is clearly an area requiring additional research. (Appendix A presents a table of estimated service lives, TBOs, and operating rates for military aircraft types.)

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

A more serious consideration, however, relative to the number of engines receiving maintenance for a given aircraft is whether spare engines (over and above those installed) should be counted in the estimating equations. We believe they should not, both because they receive only limited maintenance or overhaul and, additionally, because the Soviets would not begin to amortize them for capital repair until they actually came into service.

The annual flying time (T) must be calculated from data [redacted] In general, [redacted] computed by dividing 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.

We are, of course, assuming that the cost-estimating model and associated parameters valid for Soviet civil aviation are also valid for the military. It is worth noting, therefore, that we have examined these very closely for both intuitive reasonableness and comparability with known practices and factors for other areas of Soviet maintenance cost estimation as well as with those of the United States. This examination has not indicated the presence of notable inconsistencies and has provided no indication that the use of the civilian-derived model yields results that are qualtitatively or quantitatively "out-of-line" with other data.* Indeed, we feel 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 23, and reducing, the following generalized CER can be written:

$$TC^{y} = ((1.25 N_{a} k_{a} + 0.2375) / L_{a}^{y}) P_{a} + ((0.375 N_{e} + 0.2375) / L_{e}^{y}) EP_{e} .$$

As in previous formulations, the first term in the expression calculates maintenance cost for the airframe, avionics, and fixed weaponry, while the second does the same for the engine(s). Though the CER is written to estimate annual costs, it could be just as easily used to compute hourly expenses--once the appropriate substitutions had been

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

made. Values for P, N, E, and L 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.

In certain cases, only price and number of engines are available as data for a given Soviet military aircraft. Or, even though we do possess a complete set of values, it might be desirable to perform a "shorthand" form of the calculation. In both instances, we can use a generalized version of the CER, substituting typical values for N and L.

Thus, if an airframe is assumed to be overhauled four times and have a life of fifteen years and an engine to be overhauled twice and have a life of five years,* the CER may be rewritten as:

$$TC^{y} = (0.333k_{a} + 0.0158) P_{a} + 0.1975EP_{e} .$$

In the 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:

$$TC^{y} = 0.07125P_{a} + 0.1975EP_{e} .$$

Results

Based on the cost estimating relationships developed above, the Soviet Union probably spent about four to five billion rubles** in 1978--between seven and nine percent of its total defense spending in that year--for military aircraft maintenance. This amount would include all direct

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* These values are chosen for heuristic purposes only and do not necessarily represent our best estimates.
** Expressed in constant 1970 prices.

and indirect expenses associated with maintaining the USSR's aircraft order of battle with the exception of uniformed personnel costs. Accordingly, military aircraft maintenance appears to carry--by a wide margin--the highest price tag of any of the Soviets' maintenance requirements.

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 in the same fashion the Soviets do. Again using our Soviet CERs, but this time substituting equivalent dollar prices for aircraft into them rather than ruble prices, we find the estimated cost of Soviet military aircraft maintenance to be equal (in constant 1977 prices) to between five and six billion dollars for 1978.

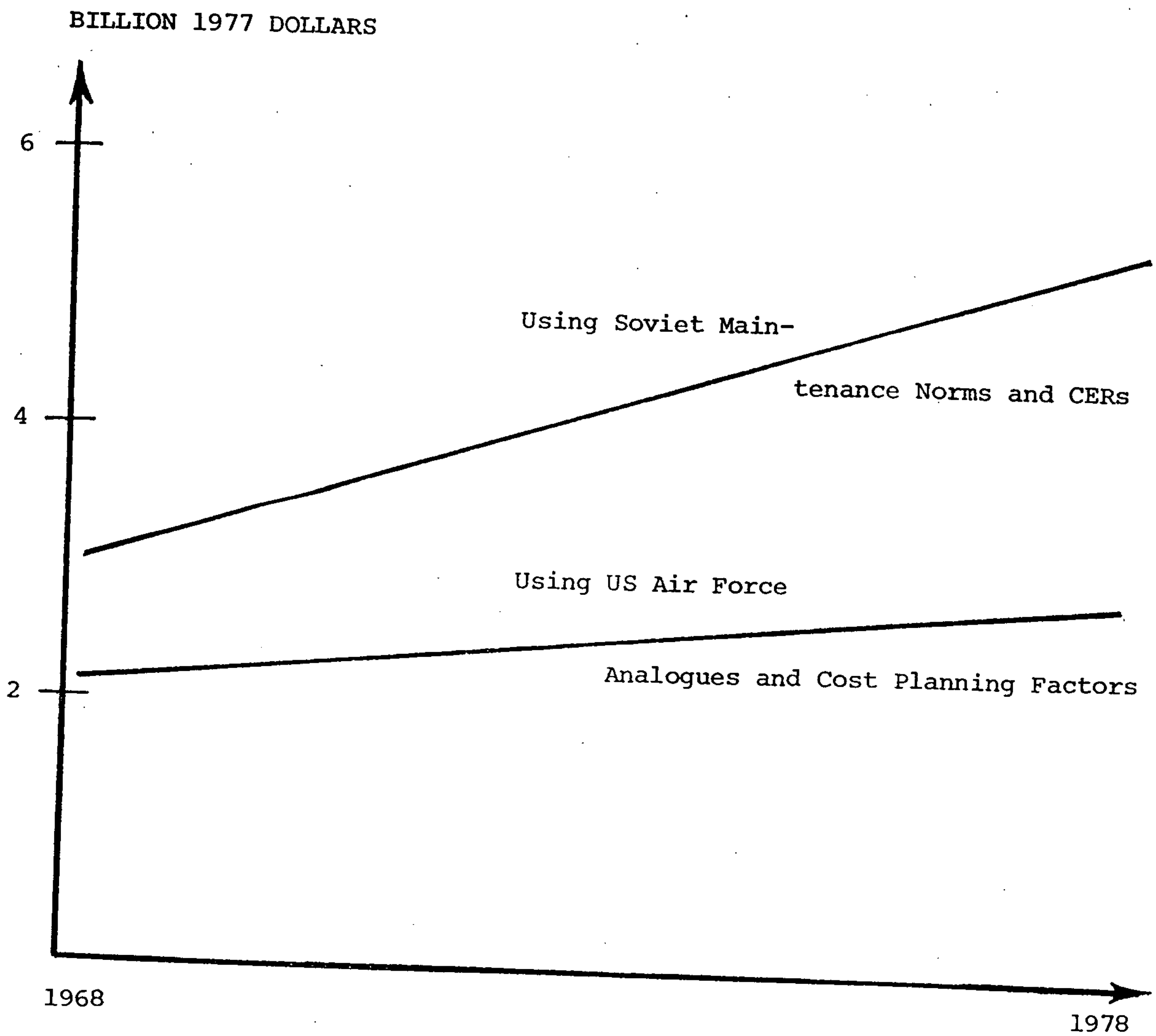
Our dollar estimates provide a good vehicle for comparing the results of the Soviet CERs with those that might be obtained from the use of USAF analogues and cost planning factors.

Figure 1 presents such a comparison for the period 1968 through 1978. In this figure, the lower line indicates the possible trend in Soviet military aircraft maintenance costs if they were estimated by using USAF analogues and CERs but adjusted for lower Soviet operating rates. The upper line indicates the trend derived by applying the Sovietized CERs developed above.

Soviet military aircraft maintenance costs as estimated by USAF cost planning factors grow from a little over two billion dollars in 1968 to just under three billion dollars by 1978, an average annual increase of three to four percent. The use of Soviet CERs results in an average annual rate of growth of six percent, nearly double that implied by the other methodology. The Soviet CERs also provide a cost series that is, on the average, 70 to 80 percent higher in level.

A number of reasons account for the sharp differences between the two estimates:

FIGURE 1. ESTIMATED COSTS OF SOVIET MILITARY AIRCRAFT MAINTENANCE, 1968-1978



(Note: The trends depicted above have been smoothed.)

-- The USAF factors are based directly on US operating rates, aircraft technical characteristics, and maintenance norms. Even though they have been adjusted to fit Soviet practices, these factors are strongly biased toward describing a maintenance system that is structured much differently than that of the USSR.

-- The USAF cost factors include only a limited amount of overhead and indirect costs, whereas the Soviet CERs account for all costs--save those of uniformed personnel--associated with aircraft maintenance (including the costs of purchasing and operating major pieces of support equipment).

-- The USAF factors--when applied to the Soviet air order of battle--tend to be static and only partially reflect changes in complexity and costliness of equipment. Because they are keyed primarily to variables such as weight and operating rate and must be applied by selecting existing analogues for Soviet aircraft, they are imperfect indicators of changes in maintenance costs resulting from technological and performance improvements in a non-US aircraft fleet. On the other hand, the Soviet CERs are principally dependent on the unit price of aircraft, a variable which--when controlled for inflation and adjusted for series production and productivity--does reflect substantive changes of this sort over time.

Because the Soviet CER method better reflects the more costly nature of the Soviet maintenance system as well as the rapid growth in cost of aircraft entering the Soviet air order of battle, this approach appears to be preferable to that based on US Air Force analogues.

APPENDIX A

Estimated Annual Flying Times, TBOs, and Service Lives for Soviet Military Aircraft*

			Airframe		Engine	
Aircraft Type	Force or Service**	Annual Flying Time (hrs.)	TBO (hrs.&yrs.)	Service Life (hrs.&yrs.)	TBO (hrs.&yrs.)	Service Life (hrs.&yrs.)
Fighter/Interceptor; Fighter-Bomber; Medium Range Bomber	FA PVO,NAV	100 150	400; 6-7	1600-2000; 12-15	250; 3-4	500-700; 6-7
Intermediate Range Bomber	LRA,NAV	100	400; 6-7	1600-2000; 12-15	250; 3-4	500-700; 6-7
Long Range Bomber:						
- Jet	LRA,NAV	120	5000; 6-7	15000; 15-20	2000; 3-4	6000; 6-10
- Turboprop	LRA,NAV	220				
ASW/Seaplane	NAV	220	5000; 6-7	15000; 15-20	2000; 3-4	6000; 6-10
RECCE; Early Warning	FA PVO	100 220	Norms are same as for like model aircraft in other roles.			
Trainer	All	160	Norms are same as for combat or transport variant.			
Fixed Wing Transport	All	600+	5000; 6-7	15000; 15-20	2000; 3-4	6000; 6-10
Rotary Wing:						
- Transport	All	220	2000; 6-7	8000; 15	600-1000; 3-4	2000; 7-9
- Combat/Assault	All	150-220				

* 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.

** FA = Frontal Aviation; PVO = APVO Strany (Air Defense); LRA = Long Range Aviation; NAV = Naval Air. Also included in the category of "all" are: VTA, MTA, Ground Forces, and Strategic Rocket Forces.