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Soviet Weapon-System Acquisition

By

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FOREWORD

The book was researched and written by James H. Irvine, a member of the Fleet Engineering Division's Systems Management Office at the Naval Weapons Center. The Office, under the direction of George F. Barker, is responsible for transitioning newly developed conventional weapons into production. The research was undertaken to ascertain if the Soviet methodology of transitioning a weapon into production and subsequent manufacturing management differed significantly from U.S. practice and, if so, whether there were aspects of the Soviet methodology that could be usefully applied in managing U.S. weapons in the production-engineering and deployment-to-manufacturing stages. At the request of Chris R. Peterson, Head of the Fleet Engineering Division, the study was expanded to cover Soviet policies for logistical support of equipment.

At the time of this book's publication, the political and economic structure of the Soviet Union and the Warsaw Pact is undergoing fundamental change. Institutions once sacrosanct are being modified and even abandoned, and concepts once foreign to the Soviet culture—free and open political debate, a market economy, genuine democracy—are now matters of common public discussion and may in fact become political realities. Nevertheless, the armed forces of the Soviet Union remain today one of the most powerful military entities in the world. As with every aspect of Soviet society, the organizational infrastructure through which Soviet military forces conceive, design, test, and field their military equipment cannot remain unaffected by the winds of change. It is likely, however, that this will be a change of degree, rather than of kind. While the emphasis on the production of military goods relative to that of consumer goods may shift, and the number of rubles channeled into the nation's war machine may dwindle, the way in which the military equips itself for battle is unlikely to be substantially altered.

The research was conducted from 1987 to 1990 using only unclassified, publicly available sources. All conclusions, projections, and opinions contained herein are the author's (except where otherwise noted) and do not necessarily reflect the views of the Naval Weapons Center, the Department of the Navy, or the Department of Defense. It is the author's hope that, through an examination of the Soviet's acquisition system, the reader may gain a better understanding of that nation's military capabilities and may also develop a new perspective on the strengths and weaknesses of our own acquisition system.

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INTRODUCTION

Two great powers, with their friends and allies, divide the world between them. To understand the industrial armament policy of either of them, one must understand the armament policy of the other. At present, "the Soviet Union . . . is one of two countries in the world to produce the full range of modern armaments."[1] That fact, along with the Soviets' nuclear capability, qualifies the nation as a superpower. In maintaining its arms industry, the Soviet Union has at any given moment between 50 and 200 major weapon systems in development and production.[2] The purpose of the vast Soviet military establishment and its supporting industrial complex is to defend the Soviet motherland, and the Soviets provide a fascinating study in the industrial management of an armament program.

The Soviet Union is fundamentally a self-contained land power with internal lines of communication facing an alliance of maritime power. The Soviet military force structure reflects that geopolitical reality; its major force is a huge mechanized land army augmented by two air forces—one to support the army (voyenno-vozdushnyye, sily) and one to defend the homeland (voyska protivovozdus-hnoy oborony, strany)—and an auxiliary navy. As a result, "the power of the Soviet forces wanes drastically as the distances from the Soviet Union increase,"[3] though both the Soviet Navy and the Soviets' ability to project power beyond its borders have improved markedly in the past decade.

The Soviet Union has built the largest peacetime military establishment in the history of the planet, a force whose size dwarfs any military establishment in the West. Only the combined efforts of the collective Western alliance can approach the Soviets' armament effort. The Soviet Union, in support of its military goals, has dedicated a larger share of its natural and industrial resources year after year to the production of military

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1 Ronald Amann, Julian Cooper, and R. W. Davies, eds., "Innovation in the Defence Sector," in *The Technological Level of Soviet Industry* (New Haven: Yale University Press, 1977), p. 276.

2 Thomas B. Cochran, William M. Arkin, Robert S. Norris, and Jeffery I. Sands, *Nuclear Weapons Databook. Volume IV, Soviet Nuclear Weapons* (New York: Harper and Row Publishers, 1989), p. 72.

3 Edward N. Luttwak, *The Pentagon and the Art of War* (New York: Simon and Schuster, 1984), p. 118.

weapons than has any other country in peacetime;[4] estimates of the Soviet military expenditure run as high as 15% of the gross national product (GNP).[5] As a result, the Soviet Union has a military production complex consisting of 134 major final-assembly plants supported by 3,500 individual factories and related installations.[6] The industrial specialization of the major plants is as follows:

Ground forces materiel	24 plants
Naval materiel	24 shipyards
Aircraft materiel	37 plants
Missile materiel	49 plants

The geographic distribution of the production centers is shown in Figure 1.

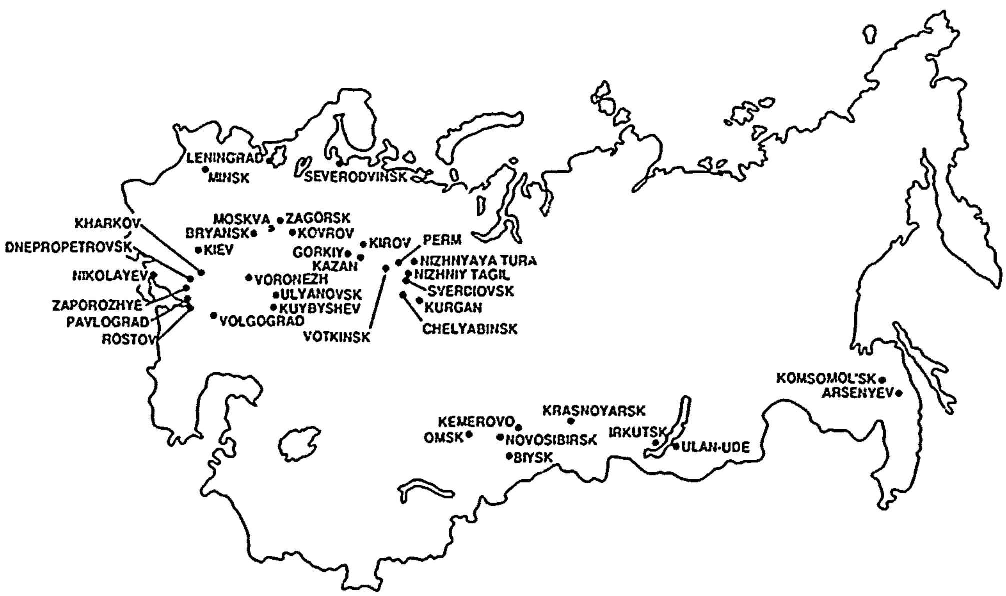

FIGURE 1. Key Soviet Military Production Centers.

Another 150 plants produce military electronic equipment.[7] This military production complex permits the Soviet Union to produce 2,700 tanks and 4,500 other armored fighting vehicles, 3,500 artillery pieces, and 950 tactical aircraft each year,[8] while at the same time producing nine classes of submarine and eight classes of major surface

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4 Edwin Schnepf and Michael O'Leary, "The Department of Defense Report on the Soviet Union's Military Threat to the United States and Its Allies." *Soviet Military Power* (commercial reprint of U.S. Government publication), Canoga Park, California: Challenge Publications, Inc., 1984), p.45.

5 Michael MccGwire, *IEEE Spectrum*, November 1988, p. 34.

6 Nicole Ball and Milton Leitenberg, *The Structure of the Defense Industry* (New York: St Martins Press), Table 2.4, p. 56, and David Holloway, *The Soviet Union and the Arms Race*, 2nd ed., (New Haven: Yale University Press, 1984), p. 118.

7 Schnepf and O'Leary, p. 45.

8 Schnepf and O'Leary, p. 88.

combatants in shipyards.[9] Against this background of massive military production—a level seen only once before, in the United States during World War II—we will discuss the strategy, philosophy, and methodology that guide Soviet weapons acquisition.[10]

CONVENTIONAL ARMAMENT STRATEGY

The Soviet Union operates on a different conventional-armament strategy, both in armament policy and logistics philosophy, than does the United States or the other nations of the West. This difference presents a problem to Western analysts who tend to view the Soviet system of weapons acquisition as a mirror image of their own societies' weapons-acquisition methodology.[11]

The Soviet system is not the result of theoretical military philosophy but rather of Soviet military experience in two world wars. In World War I, the Russian empire of the czar experienced huge equipment shortages. The Russians, even though they had 20 million men, found that they could not wage war effectively because they could not equip and arm such a large number. This lesson was reinforced by the huge losses in World War II: Soviet equipment losses in battle amounted to about seven times the Soviet weapons inventory at the end of the War.[12] As a result of these experiences, the Soviet Union has developed a firm belief in the "quantity theory of armaments," which is quite different from the technology-based quality armament philosophy of the West.[13] The Soviets believe in a war of attrition in which quantity of military equipment counts more than quality.[14] This philosophy is often summarized in Soviet military literature by Lenin's quote: "Quantity has a quality all its own."[15]

What the Soviet military leadership wants in the way of equipment is a lot of it. To get it, the leaders and their design personnel are prepared to sacrifice technical sophistication, quality, overall capability, and even some performance and reliability.

9 U.S. Department of Defense, *Soviet Military Power* (Washington: U. S. Government Printing Office (GPO), 1987), p. 105.

10 Luttwak, 1984, p. 97.

11 David C. Isby, *Weapons and Tactics of the Soviet Army* (London: Janes Publishing Company, Ltd., 1981), p. 28.

12 John Erickson, Lynn Hansen and William Schneider, *Soviet Ground Forces: An Operational Assessment* (Boulder: Westview Press, 1986), pp. 10-12. The Soviet Union deployed some 104,000 tanks and self-propelled guns during the war, but only 15,000 survived and were operational by VE day.

13 Subrata N. Chakravarty, *Forbes Magazine*, 15 September, 1980, p. 49.

14 Terry E. Dunlavey, "Soviet Weapon Systems Design Philosophy," *Program Manager*, September-October 1986, p.3.

15 Chakravarty, p. 54.

Whether this quantity-based armament philosophy is a credible basis for a war-fighting grand strategy is a subject of much debate among military philosophers; nevertheless, it is the governing philosophy of the Soviet system. This commitment to quantity leads the Soviets into a very different logistics and weapons-design philosophy than that which guides the world's other advanced military powers.

LOGISTICS PHILOSOPHY

Western armies are organized on a continuous supply-and-replacement basis. Army units are expected to go into battle and fight more or less continuously and be replenished with personnel and consumable stores (ammunition, food, and fuel) while still engaged with the enemy. This type of organization requires a unit-based maintenance system in which each unit's personnel perform most maintenance on their equipment and are supplied in the field with whatever spares they need from their supply system.

The Soviets' experience has taken them in a different direction. Their logistics system works on an echelon-combat and unit-replacement system. Under the Soviet system, units are expected to fight in echelons, each unit fighting for some period of time before being replaced as a whole at the combat front by the unit in echelon behind it. The front-line then retires to the rear to be replenished and resupplied.

This echelon method of combat management pervades the entire Soviet military planning and logistics philosophy; each unit is expected to go into combat with its initial load of consumables, fight until those consumables are expended (normally about 3 to 5 days of hard fighting),[16] and then withdraw and be resupplied. And, while it is true that the Soviet logistics system does supply replacement consumables for troops engaged in combat, even here the influences of the echelon method appear in the supply norms for the Soviet army. Supplies are delivered only to units experiencing extraordinarily high rates of consumption because of rapid movement, offensive breakthrough (or their attempts), or an extremely active defense against enemy offensive action. The rest of the army units live from the initial supply base.[17] Even when field-level supplies are furnished, the Soviet supply norms are built on the echelon assumption and the system issues ammunition, petroleum, oil, and lubricants (POL); technical supplies;[18] rations, and medical supplies in

16 Viktor Suvarov, *Inside the Soviet Army* (New York: MacMillan Publishing Company, Inc., 1982), p. 176, and Erickson, Hansen, and Schneider p. 61.

17 Isby, p. 61. A unit normally carries a 5-to-6 day supply of ammunition; petroleum, oil, and lubricants (POL); rations; and other requirements with another 1 or 2 day's stock carried in the rear and held at army level.

18 Lt. Col. William Baxter, U.S. Army (Ret), *Soviet AirLand Battle Tactics* (Novato, California, Presidio Press, 1986). The term as used here means replaceable consumables, such as, tires, tank tread sections, oil filters.

that order.[19] Spare parts and replacement weapons are not included in field-level supplies because the assumption is made that these items are in adequate short-term supply and will be resupplied to the unit at its echelon replacement point when the unit is withdrawn from combat for its rest interval.[20]

The methodology by which the Soviets plan their echelon replacement strikes a Westerner as odd. Soviet society is run by norms, however, which the *Soviet Military Encyclopedia* (Vol. 5, p. 636) defines as

> Norms-(military) (normativy (voyen)):
>
> (1) operational-tactical numerical quantities used to characterize space and time factors for operational or tactical activities of forces and the areas in which they take place. Space factors include depths of objectives, widths of sectors, dimension for combat formations—widths, depths, etc. Time factors include the time to fulfill every mission, complete marches or maneuvers, etc. These are developed based on the makeup of Soviet formations, their capabilities, enemy capabilities, combat and exercise experience, level of training, results of special research studies, terrain, weather, and time of day. The basic operational-tactical norms are reflected in regulations and directives.
>
> (2) timeliness quantitative, and qualitative factors for fulfillment by service-persons and small units (usually battalion and smaller) of specified tasks, methods or applications of weapons or technology in the course of combat preparation. Norms ensure a uniform and objective approach to the determination of times for the fulfillment of (combat) actions and for the evaluation of the level of training of service-persons and units (up to regiment) as a whole.
>
> Norms (normy) are listed under four headings: financial, supply, exploitation, and expenditure. The first three are essentially logistical while the last is both logistical and operational. The norms cover all material requirements for military personnel, units, and formations in both peace and war. In combat, norms establish, for example, how many artillery rounds are needed to destroy a given target and how many guns, planes, or tanks will be required for a kilometer of front in a conventional situation.[21]

These norms are all-pervasive in Soviet military practice and include every aspect of military life (and life in the rest of Soviet society as well).[22] Norms exist for consumption of food, temperature of barracks, amount of sleep, number of hours of training, the number of hours of instruction in party doctrine, and so on. These norms appear in field service regulations and in military writings at all levels. Since the norms reveal so much

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19 Isby, p. 62 and Erickson, Hansen, and Schneider p. 61.

20 Isby, p. 62. It should also be noted that these supplies are furnished on a unit resupply basis so as to re-equip the unit with everything it needs to go on fighting for another block of time.

21 Erickson, Hansen, and Schneider, p. 142.

22 Erickson, Hansen, and Schneider, p. 142.

about the Soviet army, most of them are classified and revealed only on a need-to-know basis.[23]

Among this collection of classified norms is a set that we have never seen, but whose existence we know of from various articles in Soviet military journals and books that discuss the standards of replacement and resupply of units withdrawn from battle under the echelon-replacement system. These norms, probably presented in chart form in the Soviet manuals, specify rest and replacement time. They say in effect that "a unit that has been in such-and-such level of combat for so many hours (or days) and has suffered such a percentage level of casualties is entitled to so many days to rest and re-equip."[24] This sounds callous to a Western observer, particularly when Soviet military writers start talking in casualty rates of 20 to 60% of the force involved; nevertheless, it is the Soviet way.

Another aspect of Soviet logistics philosophy that differs from the Western approach is that the Soviets do not fill units to strength with replacements the way the West does. Instead, the Soviets allow the unit's size to shrink as a result of the casualties suffered, with the unit often being reorganized into a smaller structure. In this manner the number of companies in a battalion or the number of battalions in a regiment is reduced.[25] By this process, a regiment can shrink to a battalion and even to a company. While some shifting of officer and speciality personnel occurs, for the most part soldiers in a Soviet unit stay together. Unit cohesiveness is believed to have significant psychological benefit to personnel in combat because troops that have fought together and learned to trust each other develop a sense of camaraderie and unity that has a positive effect on combat effectiveness and morale.[26] The process also eliminates some of the psychological problems caused by feeding in new and (to the unit) untried personnel in a combat environment.

Soviet doctrine states that at some point, a unit has been so decimated by causalities that it can no longer be an effective fighting force and must be dissolved. The Soviet norms appear to have a set time-versus-casualty criteria for dissolution (somewhere between 40 and 60% of effective combat strength after some classified period of time—probably 3 weeks or less—at a certain level of combat intensity). At the breakup point, the unit is dissolved and its personnel are sent to the rear where they, along with the components of other dissolved units, reservists, and new recruits, are formed into a new major fighting unit.

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23 Erickson, Hansen, and Schneider, p. 142.

24 Erickson, Hansen, and Schneider, pp. 143-146.

25 Erickson, Hansen, and Schneider, p. 129.

26 This continuous-unit personnel system is carried even further in some other armies (and to its extreme by the British regimental system) and is the basis, in modified form, of the experimental new manning system in the U.S. Army.

The echelon-based combat-personnel and -supply system leads the Soviets into weapon-replacement and -maintenance philosophies quite different than those followed by any Western army.[27] The Soviets operate on a whole-weapon replacement system based on their experiences during World War II. During that conflict, the Soviets found that the combat life of a piece of equipment on a modern battlefield was terribly short.[28] Not only was the wastage of equipment in modern battle high, but also the type of damage and abuse it received in a combat environment was generally so severe that it could not be repaired and maintained under field conditions. This led the Soviets to adopt a philosophy whereby they expect to send a tank or other piece of military equipment into battle, have it blown up, and then have it replaced with a new one.[29] The Soviets believe that the life expectancy of equipment on a modern battlefield is so short that it is easier for a modern industrial sceiety to build new equipment than to repair that which gets damaged and worn out. As a result, Soviet planners and weapon designers think of a pieces of equipment as short-term disposable items rather than pieces of long-term capital equipment (as Western military thinkers consider their equipment). Because the Soviets treat weapons as consumables, they have not built a massive field-level maintenance-and-support organization to support their troops in combat.[30] The lack of a complex logistics and materials tail[31] along with the lack of a large dedicated training base in the maintenance area, are often noted in Western literature as examples of the low technical competence of entry-level Soviet military personnel.[32, 33] The analysis is probably incorrect. There is little doub. that if the Soviets wanted to, they could develop a more comprehensive logistics and maintenance support structure. The lack of such a structure is a result of the whole-weapon replacement doctrine.

The doctrine of whole-weapon replacement raises the question of how the Soviets plan to support the equipment they do have in the field. The answer is first by design, and then by cannibalization. The Soviet weapon-replacement and -use philosophy places a premium on ruggedness and simplicity in design. Soviet equipment is designed "for limited field maintenance by relatively unskilled personnel . . . ."[34] The design position is that if you make it rugged enough, it won't break and, therefore, you won't have to repair it.

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27 Suvarov, p. 175.

28 Progress Publishers, *Marxism-Leninism on War and Army*, p. 220.

29 Norman Friedman, "The Soviet Mobilization Base," *Air Force Magazine*, March 1979, p. 65.

30 Suvarov, pp. 76-77.

31 Isby, p. 61. The Soviet armed forces average only 0.68 logistics, service, communication and support soldier for each fighting soldier as compared to 3.285 to 1 for the U.S.

32 J.W. Kehoe and K.S. Brower, "U.S. and Soviet Weapon System Design Practices," *International Defense Review*, June 1982, p. 706.

33 Isby, p. 61.

34 U. S. Department of Defense, *Soviet Military Power* (Washington, GPO, 1986), p.112.

The second support methodology, cannibalization, is facilitated by the Soviet policy of using standard components and parts wherever possible.[35] The Soviets expect the battlefield to be littered with damaged and broken-down equipment that has been discarded or abandoned by their troops. This equipment can be easily cannibalized by the troops to provide the spare parts needed to keep their equipment running.[36] The cannibalization operation is largely a major-component change-out operation that can be performed by the "diverse mechanic" (voditel'-mekkanik)[37] with minimal training, so high levels of maintenance skills need not be taught to the troops. The rest of the abandoned, damaged, and now cannibalized equipment is left for specialized recovery and materials units whose job it is to collect the abandoned equipment and piece together operating units by cannibalization.[38] This field-rebuilt equipment is then used to arm the new fighting units formed by the personnel of the dissolved units under the echelon-replacement system.[39]

The Soviet logistics philosophy of maintenance by battlefield cannibalization seems strange to a person steeped in Western maintenance practices; in 1948, however, it was seriously proposed for adoption as the spare-parts supply system for the U.S. Army by Wilfred G. Burgan, the U.S. Army's senior civilian maintenance officer at the Supply Group Staff Conference. Mr. Burgan's position, based on analyses of World War II experiences, was that "modern warfare precludes higher echelon maintenance in combat zones."[40] He asserted that wartime experiences showed that "15% of the different types of spare parts issued during World War II had met approximately 85% of all combat zone maintenance needs"[41] and that the U.S. would be better off not stocking the 85% and relying instead on the tear-down cannibalization of damaged vehicles in the combat zone as its wartime basis.[42] The U.S. chose not to adopt this recommendation. The Soviet system may have some shortfalls in peacetime, but it clearly does have a rational combat-experience basis.

The Soviets maintain their equipment during peacetime in about the same way as they plan to do in wartime. That is why the logistics tail is so much smaller than those of the United States and other Western powers. The Soviets, even in peacetime, rely to a great extent on the simplicity and ruggedness of their equipment to minimize maintenance requirements. Some troop-level maintenance exists, such as change-out of components and routine maintenance (oil changes, etc.), but there are no significant intermediate-

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35 Baxter, p. 219.

36 Erickson, Hansen, and Schneider, pp. 127-128.

37 Baxter, p. 217.

38 Baxter, pp. 218-221.

39 Suvarov, pp. 175-178.

40 Harry C. Thomson and Lida Mayo, *The Ordnance Department: Procurement and Supply* (Washington: GPO, 1959), p. 319.

41 Wilfred G. Burgan, *The Spare Parts Problem and a Plan*, (Encl. to Dept. of the Army Ltr., 6 April 1948, A GAM-PM 451.9, 30 March 1948).

42 Thomson and Mayo, p. 319.

maintenance overhaul facilities or organization as in Western armies. While there is a centralized higher-level maintenance organization, it operates centralized maintenance points for a given piece of equipment. Such a maintenance point often operates in conjunction with the factory that builds the equipment (usually at only one place in the Soviet Union), which is more like a rebuild facility than what a Westerner considers a maintenance facility.

Very few spares are provided for Soviet military equipment during peacetime. Whether this is entirely a matter of military logistics philosophy (choosing even in peacetime to rely on the inherent ruggedness of the design of the equipment), or merely a reflection of the spare-parts problem of the Soviet economy as a whole, is debatable. The Soviet industrial and consumer economy suffers from a chronic famine of spare parts for machinery (the Soviet military may actually be better off than the civilian economy, even though the military's plight would send a Western logistician into convulsions).

The lack of spare parts in the Soviet Union is a result of an industrial incentive system that gives bonuses to factories and their managers and workers based on how many whole units they produce. The system actually counts spare parts negatively: how many whole units were not produced that could have been made from the spare parts that the factory shipped? This industrial incentive system has resulted in a spare-parts famine throughout the Soviet economy.

Several books, both Western and Soviet, have been written on the Soviet spare-parts problem. The Soviets know they have a problem and have tried various solutions over the years. Even so, little progress appears to have been made, and the Soviet press, both technical and general, still rants about the spare-parts shortage, particularly in agriculture. *Pravda* has complained that as much as one-third of the agricultural machinery of the Ukraine has been standing idle, broken-down during the harvest season, for lack of spare parts. The Soviet Minister of Agriculture and Food Machinery is generally the most publicly disliked official in the Soviet Union, and assignment to that job is considered a death knell for a Soviet politician.

How can the Soviets survive in peacetime with such a maintenance and supply system? The answer is that Soviet equipment use in peacetime is substantially different than the West's. Soviet policy is to train personnel on a small portion of a military unit's equipment, about 10% in peacetime. The bulk of the unit's equipment remains in storage in tank parks. The stored equipment is used only twice a year, for maneuvers, and then put back into storage. This process minimizes the peacetime maintenance regimen.[43] It also greatly extends the useful service life of the equipment, particularly when compared to the rapid depreciation through use that Western military equipment suffers.

43 Friedman, 1979, p. 65.

This Soviet use policy presents an equipment-counting problem for Western arms-control negotiators. The fact that the Soviets are able to maintain very large amounts of almost-new equipment in their inventory for a much longer time than the West can has serious strategic implications for conventional-arms-control negotiations.

The proposed use of the training equipment in wartime mobilization is also interesting. The Soviets expect to abandon their "worn-out" training equipment upon mobilization and drive to war in brand-new equipment. The training equipment will be either left to the reserve units that will follow the departing mobilized troops in their cantonments, or will be sent to the staff organization involved in forming replacement units from the combat wreckage of war under the echelon-replacement system. It can be expected, in accordance with Soviet troop practice, that much of the abandoned training equipment will have been stripped of usable spare parts to make up the unofficial forward maintenance inventory of the advancing combat units.[44] Thus it can be anticipated that one of the reserve units' most urgent tasks on mobilization will be to get the abandoned training equipment back into some semblance of working order.[45]

THE STRUCTURE OF WEAPON-SYSTEM ACQUISITION

The Soviet Union's system for designing and acquiring weapons and military equipment is radically different from those of the West (either the American or European systems) in both organizational structure and design methodology. The Soviets operate a huge state arsenal complex that supplies all military equipment. Such an integrated arsenal approach has not been seen in the West since the close of the first phase of the industrial revolution at the end of the last century.

At the apex of the Soviets' highly centralized state-owned weapon-production complex is the Military Industrial Commission[46] (VPK),[47] which reports to the Council of Ministers of the U.S.S.R. The VPK, about which little information is available in the West, provides the central coordination and policy guidance for Soviet weapons acquisition and oversees all military-related research, design, development, testing, and production.[48] In this regard it appears equivalent in function to the Offices of the Secretary

44 Baxter, p. 204. The Soviet system has, and its maintenance system tends to encourage, a significant problem with troops meeting their maintenance requirements by "moonlight" requisitioning of parts from the war reserve equipment in the tank parks (regulations strictly forbidding this practice not withstanding).

45 Whether the Soviets maintain a centralized war reserve of spare parts to do this is not known.

46 Timothy D. Desmond, "Weapon Systems Acquisition in the Soviet Union," *Program Manager*, March-April 1987, p. 18.

47 The Soviet acronyms used to identify their organizations are provided for general information.

48 MccGwire, "Allies and Adversaries," *IEEE Spectrum*, (The Brookings Institution, 1988), p. 34.

of Defense in the U.S. The VPK may make the final production decision on major Soviet weapons as well (equivalent to the Defense Systems Acquisition Review Council (DSARC) decision in the U.S.), although there is some debate in the West on this point. The Military Industrial Commission may also determine the ultimate allocation of resources between competing weapon programs.

Subordinate to the Military Industrial Commission[49] are nine Defense Production Ministries[50] that actually perform the research, design, development, testing, and production[51] of military products.[52] Each ministry specializes in a specific type or class of weapon or equipment. These are summarized as follows:

Ministry of Defense Industuy (MINOBORONPROM), (MOP)	Tanks, armored vehicles, artillery, small arms, and assorted optical equipment
Ministry of Machine Building (MINMASH), (MM)	Conventional ordnance, munitions, fuzing, solid propellants, and explosives
Ministry of General Machine Building (NUBIVAGXGWNAG), (MOM)	Missiles and space equipment
Ministry of Medium Machine Building (MISREDMASH), (MSM)	Nuclear weapons and high-energy lasers
Ministry of Ship Building (MINSUDPROM), (MSP)	Naval vessels and naval weapons
Ministry of the Electronics Industry (MINELEKTRONPROM), (MEP)	Electronic components and parts
Ministry of the Radio Industry (MINRADPROM), (MRP)	Radars, communication equipment, guidance-and-control systems, navigation equipment, and military computers
Ministry of Communications Equipment Industry	Telecommunications and radio equipment, satellite com-

49 Mikhail Agursky, *The Soviet Military Industrial Complex* (Jerusalem, Israel: The Magnus Press, The Hebrew University, 1980), p. 6.

50 Harriet F. Scott and William F. Scott, *The Armed Forces of the U.S.S.R.* (Boulder: Westview Press, 1979), p. 173.

51 Desmond, p. 18.

52 Agursky, p. 6.

(MINPROMSVYAZ), (MPSS)	munications equipment, and electronic warfare (EW) equipment
Ministry of Aviation Industry (MINAVIAPROM), (MAP)	Aircraft, missiles, helicopters, and aircraft engines[53, 54, 55, 56, 57, 58]

Large quantities of military equipment are also produced in some of the so-called civilian ministries; for example, the Ministry of Motor Industry also produces military motor transport and amphibious vehicles, the Ministry of the Chemical Industry produces chemical warfare agents and fuels, and the Ministry of Electrical Equipment and the Ministry of Instrument Building produce military precision instruments.[59]

Each of the nine production ministries oversees the network of research institutes, design bureaus, production facilities, and test centers needed to design and produce its specialized products.[60] Some of the ministries (but apparently not all) also have specialized technical schools, academies, and higher-education establishments associated with their networks.[61]

One feature that all the ministries have in common is that they are large and vertically integrated. Because the Soviet Union's centrally planned economy tends to have a general shortage of materials,[62] which in turn results in unreliability of supplies,[63] the ministries try to become as self-sufficient as possible to ensure greater control over their supply bases.[64] "The Ministry of Aviation Industry . . . produces sheet aluminum, magnesium alloys, shaped metal products, plastics, and rubber products. Commonly used components such as instruments, machine tools, rivets, nuts, and bolts, instead of being

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53 Agursky, p. 6.

54 Desmond, p. 18.

55 Ronald Amann and Julian Cooper, *Technical Progress and Soviet Economic Development*. Basil Blackwell, 1986, p. 32.

56 William F. Scott, "Moscow's Military-Industrial Complex," *Air Force Magazine*, March 1987, p. 47, and Scott and Scott, p. 295.

57 Douglas J. Murray and Paul R. Viotti, eds., *The Defense Policies of Nations* (Baltimore: The Johns Hopkins University Press), 1982, p. 167.

58 Westwood, *A Survey of Soviet Engineering and Technology for Military Applications* (China Lake, California: Naval Weapons Center), 1988, p. 142.

59 Amann and Cooper, 1986, p. 32.

60 Westwood, p. 142.

61 Amann, Cooper, and Davies, p. 314.

62 This shortage is the result of overly optimistic goals in plans and of underfulfilled targets, rather than poor planning.

63 Murray and Viotti, p. 174.

64 Murray and Viotti, p. 168.

produced efficiently by a single supplier, are manufactured by branches of the defense industry"[65] (for their own use). Even so, defense ministries tend to be departmentalized according to classes of products or weapon systems produced.[66]

Many of the Soviets' 3,200 research institutes are also engaged in military-related research. This research complex (Figure 2) may well be the most extensive military-industrial research complex in the world.

FIGURE 2. Key Soviet Research, Development, and Test Centers.

While there is some variation between ministries,[67] the same basic organizational structure appears throughout the Soviet military R&D system.[68] Ministries are organized internally into a four-tiered system consisting of research institutes, design bureaus, production facilities, and test centers.[69]

Research institutes perform both theoretical and applied research into areas of interest to the ministry, and each ministry, in general, has a wide variety of research institutes working for it. Some research institutes examine basic areas of technology (aerodynamics, for example); the materials associated with the ministry's main product

65 Murray and Viotti, p. 168.

66 Desmond, p. 17.

67 Murray and Viotti, p.169.

68 The same pattern appears in Soviet civilian R&D as well.

69 Arthur J. Alexander, *Weapon Acquisition in the Soviet Union, United States, and France* (Santa Monica: The Rand Corporation), 1973, p. 427.

(armor plate, for example); and production technology. Research institutes also develop the general and specialized technology of the weapon systems themselves.[70] For example, the MAP has "an impressive array of research organizations, including the Central Aerodynamics Institute and the Central Scientific Research Institute of Aviation Motor Building;"[71] several research institutes that work on lightweight metals and other aerospace materials; and several other institutes that are devoted to the production and fabrication problems of the aerospace industry.[72]

Research institutes engage in applied research in weapons and production technology.[73] This technology is transferred, in the form of a wide array of technical handbooks, to the design bureaus.[74] The handbooks provide guidelines and procedures for the design of components and subsystems, materials selection, and fabrication technologies to be used in the design and production of material for the ministry.[75]

Design bureaus (konstruktorskoe byuro, KB) design and develop weapons, components, subsystems, and new production processes.[76,77,78] About fifty design bureaus in the Soviet Union work at developing major military systems. These bureaus are divided into various specialities as listed in Table 1,[79] and are supported by approximately 250 subsystem- and component design bureaus,[80] as well as process-development design bureaus.[81] Each design bureau in a ministry is a specialized design organization working in a single area of interest.[82] The MAP, for example, "has eight aircraft design bureaus and seven air-breathing-missile system design bureaus that are supported by sixteen component

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70 Franklin A. Long and Judith Reppy, *The Genesis of New Weapons* (New York: Pergamon Press, Inc., 1980), p. 143.

71 U.S. Department of Defense, 1987, p. 109.

72 The Ministry of Aviation's research structure has been extensively written about in the open literature, both in the U.S.S.R. and in the West; as a result, we know more about it than any of the other ministries, and it is often used as the example in studies. The MAP structure is larger and more complex than most others and may, therefore, not be truly representative. For more background on MAP organization see "R&D in Soviet Aviation" R-589-PR, (Santa Monica, California: The Rand Corporation, 1970).

73 Long and Reppy, p. 143.

74 Desmond, p. 17.

75 Amann, Cooper, and Davies, p. 316 and Alexander, 1973, p. 427.

76 Amann, Cooper, and Davies, p. 316.

77 Long and Reppy, p. 143.

78 While most engineering development is done in design bureaus, this is not the pattern for certain high-technology products. Ballistic missiles for example "are designed in research institutes of the Ministry of General Machine Building." (Murray and Viotti, p. 169.). This may well be the case for any highly advanced technology that is considered too advanced to turn over to an engineering organization (Amann, Cooper, and Davies, p. 317). This may be the organizational path followed by the Soviets in both nuclear weapons and high-energy lasers.

79 Cochran, Arkin, Norris, and Sands, p. 73.

80 U.S. Department of Defense, 1987, p. 109.

81 Amann, Cooper, and Davies, p. 316.

82 Long and Reppy, p. 143.

and accessory design bureaus and ten design bureaus that develop air-breathing power plants."[83] Design bureaus that work on whole systems are generally designated as special, central, or experimental-design bureaus (spetsial'noe, tsentral'noe, or opytno-konstruktorskoe byuro) while those that work on components or production processes are generally designated project-design bureaus (proektno-konstruktorskoe byuro).[84]

TABLE 1. Soviet Military Design Bureaus.

Specialization	Number
Strategic Missiles and Space Boosters	7
Tactical Missiles	9
Aircraft	9
Ships	6
Satellites	6
Tracked Vehicles and Artillery	7
Radars	8
Total	52

The design bureaus vary considerably in size and location. In the high-technology field of aviation and missiles, design bureaus are enormous and relatively autonomous organizations with their own prototype factories and model shops.[85] In low-technology areas, such as tank and artillery development, the design bureaus are usually attached to production plants where they have experimental shops at their disposal.[86] This arrangement is also true of naval work, and most naval design bureaus appear to be attached to shipyards.[87] In this aspect of design, military organizations appear to be better off than their civilian counterparts, which often lack adequate experimental prototype and model facilities.[88]

Design bureaus are responsible for the design and development (or the upgrading)[89] of individual weapons and equipment. The bureaus are not responsible for the development of the technology (that is the function of the research institutes), nor are they responsible for production of the system (the job of series production plants).[90]

83 U.S. Department of Defense, 1987, p. 109.
84 Amann, Cooper, and Davies, p. 316.
85 Amann, Cooper, and Davies, p. 317.
86 Amann, Cooper, and Davies, p. 317.
87 Murray and Viotti, p. 169.
88 Amann, Cooper, and Davies, p. 317.
89 Desmond, p. 7.
90 Kehoe and Brower, p. 705.

Production plants belong to the ministry. In the case of the MAP, about 30 or 40 manufacturing plants exist.[91] "Series production plants are not permanently linked to a specific design bureau, although there are some traditional bonds between a plant and a designer that may extend over several decades."[92] In this way a production plant is intended to assume work from any design organization in the ministry to which it belongs or even from outside that ministry, though the practice of sending work to another ministry is not favored. The arrangement of design bureaus and production plants permits weapon-design and production activities to be conducted as separate businesses, which is regarded as a highly desirable feature by some Western commentators and which results in increased productivity and flexibility.[93]

One marked difference between a Soviet factory and a Western one is the degree to which the Soviet plant is self-contained. The Soviet economy's chronic supply problems and the lack of control over outside suppliers have resulted in each individual plant trying to keep as many of the manufacturing processes as possible within its own organization.[94]

Each military production ministry has at least one major test center to use when evaluating and "proving out" the equipment developed under its cognizance.[95, 96] Some of the ministries have extensive arrays of test facilities; those of the MAP include "flight and static test capabilities at Remenskoye Air Base near Moscow, diversified liquid-and-solid-rocket-propellant test stands, rocket sled tracks, and wind tunnels."[97] In addition to the ministry test centers, each of the military customers[98] has its own set of test centers where it can conduct "customer" and state tests and acceptance trials.[99]

Each Soviet weapon-design bureau is headed by an individual called the chief designer. The role of the chief designer is unique to the Soviet R&D system; he is much more influential and important than the leader of a design team in the West. In fact, design bureaus often are known (at least unofficially) by the name of their chief designer.[100] The importance of the chief designer reflects Stalin's attitude on the nature of machine design and his feelings about "the importance of avoiding complicating changes." He felt that the designer was the one individual who could be held responsible for the success or failure of a product and that the designer had the duty of protecting the integrity of his design from

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91 Kehoe and Brower, p. 705.

92 Alexander, 1973, p. 428.

93 Raymond W. Shymansky and William Holder, "U.S./Soviet Weapons Acquisition," *Program Manager*, July-August 1984, pp. 4-8.

94 Alexander, 1973, p. 423.

95 Shymansky and Holder, p. 5.

96 U.S. Department of Defense, 1987, p. 109.

97 U.S. Department of Defense, 1987, p. 109.

98 The Soviet Union's five military services.

99 Derek Leebaert, *Soviet Military Thinking* (London: George Allen and Unwin, 1981), p. 280.

100 Amann, Cooper, and Davies, p. 317.

the demands of others. The most insidious kind of degradation, Stalin thought, was the "epidemic of improvements."

> The designer must not be at everybody's beck and call . . . He has to protest irresponsible demands . . . The designer has to be tough and he has to protect his machine from irresponsible advisors. It is difficult to make a good machine and easy to spoil it. And it's the designers who are responsible.[101]

Soviet chief designers lead small, elite design teams that work together for long periods—often 25 years or more.[102] Although this core design team, headed by the chief engineer, is often supported by a large staff of assistants, the decision-making process is much more centralized than in most Western countries.[103] Some Western observers feel that long-term continuity of personnel in the design team helps explain the consistency and continuity of design characteristics in Soviet weapons systems.[104,105,106]

The length of tenure of members of the design team not only results in much experience being built up by the team, but also gives the team members a long-range perspective on their design work and weapons development.[107] This lengthy tenure is in sharp contrast to the American practice, where R&D design teams are formed for each new program and dissolved when the work is over or even when it is significantly delayed.[108]

Another point of difference is that Soviet designers continue to do design work as they attain seniority. In the West, to attain status and reward, the best designers and engineers soon get promoted out of the design shop and into managerial posts. "In the Soviet design bureaus, designers can stay at a drawing board and be rewarded with status and public acclaim."[109] The status awarded by the Soviet Union to its designers is far above that given by any Western governments to their own designers. The ideological basis for this reward is that in Soviet society, designers are workers, as opposed to "mere intellectuals." The ideology holds that workers who are successful and make significant contributions to society—such as successful designs for machinery (including military equipment)—should be rewarded with large bonuses and with medals and should be declared "Heroes of Socialized Labor."

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101 Alexander, 1973, p. 430.
102 Kehoe and Brower, p. 705.
103 The exception is France, which also uses the very small, elite design-team approach.
104 Kehoe and Brower, p. 705.
105 Jacques S. Gansler, *The Defense Industry* (Cambridge: The MIT Press, 1980), p. 253.
106 Schnepf and O'Leary, p. 57.
107 Dunlavey, p. 3.
108 Desmond, p. 17.
109 Christopher Donnelly, "Arming the Soviet Military Machine," *Jane's Defence Data,* November 1988, p. 1297.

Design bureaus, and research institutes as well, are institutionally funded. Therefore, the long-term financial future is not significantly affected by what the bureau is doing at any given time or by the success or failure of a design that the bureau currently has under development. This stability permits the design bureau to pursue a given course of development over a long period of time without having to worry about being totally successful (as measured by getting a new system into production).[110] There are some R&D establishments that have been continuously working for a decade or more on systems without putting anything into production—although there is still considerable pressure on these organizations to deliver models for state testing (see discussion under Design Methodology, below).

The continuity of institutional funding relieves Soviet design establishments of the cyclical ups and downs that affect their Western counterparts.[111,112] The stability of funding, however, also results in a static manpower base and leads to manpower being a relatively fixed, short-term constraint on the design process that requires the bureaus to seek design solutions that do not require excessive design efforts.[113,114]

High-quality manpower is attracted to military R&D and production because of large salaries and bonuses and by such perks as better housing and educational opportunities. Engineering salaries run an average of 20 to 30% higher than those in the civilian sector, and in some specialized fields and R&D organizations wages can be as much as 40 to 50% higher than civilian wages.[115] In addition, substantial state prizes and large bonuses are often distributed among members of design bureaus, providing further monetary advantages as well as a boost to morale.[116]

Educational opportunities and the possibility of obtaining advanced degrees are other inducements for high-quality technical personnel to join the Soviet military research organizations. Most of the military production ministries have their own academies and higher-education establishments to train technical specialists.[117] Some of the technical research institutes give advanced degrees in their fields of science.[118,119]

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110 Murray and Viotti, p. 169.
111 Murray and Viotti, p. 169.
112 Desmond, p. 17.
113 Alexander, 1973, p. 431.
114 Alexander, 1978, p. 28.
115 Agursky, pp. 17-18.
116 Alexander, 1973, p. 431.
117 Amann, Cooper, and Davies, p. 314.
118 Vadim Medish, *The Soviet Union* 2nd ed (Englewood Cliffs, New Jersey: Prentice-Hall Inc., 1985), p. 206.
119 This practice frustrates traditional Soviet academicians and gives rise to comments (perhaps motivated by jealousy) as to the low quality of the research institute degrees.

Secrecy and compartmentalization surround the efforts of the design bureaus and research institutes. The Soviets are secretive to a degree that strikes a Westerner as paranoid. This is a society where the maps given to tourists in Moscow have been deliberately altered (so that they cannot be used to direct artillery fire), and the card catalog of the Lenin Library in Moscow (the largest in the world) is classified as a state secret. The degree of compartmentalization and secrecy surrounding genuine military-security matters is truly astounding to the Western mind.

The Soviets have five ascending levels of security classification: Open, For Official Use, Secret, Absolutely Secret, and Especially Secret.[120] [121] Classified material in an industrial plant is controlled by the KGB staff offices, further complicating an already grossly over-classified system. All material at or above the Secret level is in the KGB's physical custody and must be returned to the KGB every night.[122]

> The effects of secrecy are rampant at all operational and planning levels. In military R&D, engineers typically work on a small piece of a mechanism, often without knowing the identity or use of the final product. Only a chief designer has the overall project in clear enough view to be able to make many of the design decisions that in other countries are normally delegated to lower levels. Secrecy retards the flow of scientific information and the efficient management of R&D because details have to be continuously referred upward for consideration. In R&D, it is one of the reasons why the chief designer has assumed his leading role in development.[123]

In the Soviet system, knowledge is so compartmentalized that those working in one department do not know what the other departments are doing.[124] Excessive secrecy and the compartmentalization of knowledge are held out by many observers "both in the Soviet Union and abroad as one of the major reasons for the backwardness of Soviet science."[125] The Soviet security arrangements also make publishing of certain types of work in open scientific literature extremely difficult.[126,127,128]

On the other hand, comments concerning the negative effect of secrecy on the design bureaus and research institutes should not be given undue weight. The Soviet

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120 Amann, Cooper, and Davies, p. 337.

121 Some authors translate the security terms differently. Agursky (p. 12) lists the five categories as Open, Confidential, Secret, Top Secret, and Top-Top Secret.

122 Amann, Cooper, and Davies, p. 336-337.

123 Murray and Viotti, 1982, p. 171.

124 Amann, Cooper, and Davies, p. 338.

125 Amann, Cooper, and Davies, p. 339.

126 Amann, Cooper, and Davies, p. 338.

127 Agursky, pp. 14-15.

128 Weapon designers in the West, however, don't publish much material in the open literature either. Publication is probably more of a problem for academic researchers, for whom publication in the open literature is tantamount to academic success and status, than it is for those in the engineering development area.

system does work reasonably and effectively for those organizations. The Soviet press produces a large number of technical/professional engineering texts of the handbook variety (which the West largely ignores). Research institutes and design bureaus have technical libraries and classified report collections probably as large as their Western counterparts. In addition, each military production ministry publishes its own secret monthly.[129, 130] A Soviet weapon design engineer probably does not consider himself starved for necessary design data, and in fact probably has the same problem as his Western counterpart: "How do I find the data I need in that pile of over-classified stuff?"

The members of the design bureaus and research institutes have found one way to turn the Soviet security system to their personal advantage. A Soviet researcher writes a report in a classified area, for which he generally gets a bonus; at the same time he also writes a technical journal article on the work. The article publication is promptly prohibited by the security system. However, the researcher is allowed to keep it with his classified papers. Ten or 15 years later, when the work is declassified, the scientist can submit his article for publication, for which he is entitled to a publication bonus. This permits the researcher to bank his future bonuses in his file drawer, something his Western counterparts cannot do. Because publication bonuses are based on one's grade level at the time of publication (and by the time publication occurs the researcher is usually more senior), he gets a senior-level publication bonus for work he did as a junior.[131]

DESIGN PHILOSOPHY

Soviet weapon-design philosophy is the product of three factors: military doctrine,[132] limitations of the technology base, and limited industrial capabilities. These factors are influenced by the Soviets' unique historical experiences. As Desmond notes, "Some people in the West have belittled Soviet technology and weaponry, but the Soviet Union turns out very respectable and technically advanced systems, often at less cost than ours."[133] They have built their weapon systems to meet the requirements of their industrial capabilities, technical proficiencies, and economic infrastructure.[134] As a result, "The

129 Agursky, p. 15.

130 These would be a virtual gold mine of Soviet R&D methodology and practice if a Western intelligence organization could obtain them.

131 Westwood, p. 57.

132 Arthur J. Alexander, *The Process of Soviet Weapons Design* (Santa Monica: The Rand Corporation, 1978), p. 14.

133 Desmond, p. 15.

134 Dunlavey, p. 2.

Soviets have a philosophical weapon-design system that works exceedingly well [for them]."[135]

As noted earlier, the Soviets are driven by historical precedent into a doctrine of quantity, the overriding principle of Soviet weapon-acquisition policy. To this end, they are prepared to sacrifice a degree of technical satisfaction and operational capability. "The Soviets are much more willing to make performance compromises to facilitate quantity production of weapons than the U.S. weapon-design system."[136] The Soviet weapon designers use designs that are well within the state of the art, choose proven technology, and keep their performance goals modest.[137]

To facilitate quantity production, the Soviets work diligently on the production engineering aspects of their weapon design—much harder than do their Western counterparts. Western analysts often cite the poor cosmetics and crude surface finishes of Soviet weapon components as an example of the poor quality of Soviet workmanship. In fact, the lack of polish on Soviet machine surfaces is a deliberate trade-off to increase producibility of parts.[138] Tight tolerances and high-grade surface finishes are generally restricted to areas where they are functionally required.[139] To further increase weapons producibility, the Soviets minimize redundancy and limit automation in their weapons [140] and take a more flexible position with regard to both their military-specification and quality-control procedures than does the United States.[141] In addition, the Soviets generally use inexpensive manufacturing processes to produce parts and components wherever possible. Because of these steps, not only is the Soviet system able to produce more equipment in a given class than the West, but equipment tends to be less expensive per unit than Western counterparts.

> Comparative cost assessment conducted by American manufacturers of ships, missiles, tanks, aircraft, and jet engines has consistently shown that Soviet systems would be relatively inexpensive to manufacture in the United States, using automated production facilities. In general, these cost studies have indicated that Soviet weapons systems could be produced in the United States for about one-third to two-thirds the cost of comparable American systems.[142]

In addition to large quantities of easily produced equipment, the Soviets want equipment that is rugged and simple. The philosophy is summarized by the maxim of

135 Dunlavey, p. 2.
136 Kehoe and Brower, p. 709.
137 Desmond, p. 20.
138 Kehoe and Brower, p. 709.
139 Dunlavey, p. 3.
140 Dunlavey, pp. 5-6.
141 Kehoe and Brower, p. 709.
142 Kehoe and Brower, p. 709.

Soviet helicopter designer Mikail Mil who regularly urged his subordinates to "make it simple, make it reliable, and make it work."[143] The Soviet passion for ruggedness and simplicity is derived from five sources.

First is their combat and maintenance doctrine. The Soviets expect their equipment to be grossly abused in a combat environment and they don't feel that they will have the time, resources, or skilled manpower to repair it; therefore, it must have sufficient ruggedness designed into it so that it won't easily break down and they won't have to worry about repairs.

Second is the belief in the value of simplicity itself: "Soviet designers realized decades ago the simple truth that only uncomplicated and reliable equipment can be successful in war."[144]

Third, "Soviet designers know that their military system is based on a large conscription army which will have relatively low technical and combat operational skills because of their relatively short period of enlistment and training."[145] Therefore, Soviet weapon designers work diligently at building simple, soldier-proof equipment,[146] far more so than their Western counterparts. As an Israeli general, a user of both American and Soviet equipment, observed: "American weapons are designed by engineers for other engineers; whereas, Soviet weapons are developed for the combat soldier."[147]

The fourth factor that drives the Soviets toward simplicity has to do with how and by whom the maintenance is performed in the Soviet army. "Soviet designers are obviously aware that they have a large conscripted Army, Navy, and Air Force without large numbers of technically proficient senior noncommissioned officers."[148] Sophisticated maintenance and repair responsibilities are assigned to officers who are "hands-on" engineers and not managers (unlike the U.S. armed forces, where maintenance and repair are performed by enlisted personnel).[149] This maintenance scheme has a definite impact on Soviet designers. It is one thing to send a private out to repair a broken bearing in a tank's oil pump; it is quite another to make a colonel get his hands greasy for 2 days doing that. If this circumstance arises very often, the Soviet designer is likely to be told that his equipment is inadequate and will be told from a high enough level to have an unfavorable influence on his career. Soviet designers appear to be fully cognizant of this sociological fact.

143 Kehoe and Brower, p. 709.
144 Suvarov, p. 182.
145 Alexander, 1978, p. 15.
146 Desmond, p. 20.
147 Kehoe and Brower, p. 706.
148 Suvarov, p. 234. Soviet noncommissioned officers are recruits who have been through a special 6-month training course.
149 Kehoe and Brower, p. 706.

The fifth factor driving Soviet weapon design toward simplicity is not derived from the military environment but is a result of the Soviet industrial management system. Soviet industrial enterprises are paid significant bonuses for meeting their output norms.[150] Factory managers in particular are severely penalized for not meeting these production quotas, so the managers look askance at anything that makes equipment more difficult to build. Great pressure from the industrial management level is placed on the designers to keep equipment as easy to build as possible and to simplify production by eliminating all the unnecessary bells and whistles.[151, 152]

These five factors drive the Soviet designer in a slightly different direction than his Western counterpart. We could probably not find a better statement of what the Soviets want from a weapon than that presented by the Soviet defector known in the West as Viktor Suvarov.

> Soviet requirements from a weapon are that it must be easy to produce and simple in construction, which makes it easier to teach soldiers to use and simpler to maintain and repair.[153]

The stress on simplicity or design has been effective. Soviet weapons have "traditionally had a lower maintenance requirement than their Western counterparts[154] because less complex weapons require less maintenance."[155] "In general, Soviet weapons are relatively uncomplicated compared with similar Western equipment"[156] and these simpler weapons "are easier to produce and usually cheaper...and yet not markedly inferior to enemy (Western) weapons."[157]

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150 Normally figured in numbers of whole units.

151 Almost the exact opposite situation exists in the American system, where the incentive is to add as much surplus gadgetry as possible in order to increase the size of the effort that one is tasked to do under the Government contract.

152 Jiri Valenta and William C. Potter, *Soviet Decision Making for National Security* (London: George Allen & Unwin, 1984), p. 101.

153 Suvarov, p. 182.

154 Isby, p. 63.

155 Chakravarty, p. 61.

156 Alexander, 1978, p. 20.

157 Alexander, 1978, p. 15.

DESIGN CULTURE

Westerners look at Soviet equipment through Western eyes. Soviet equipment is the result of a different design culture, and, this culture and the differences that it creates in the final product are often overlooked or ignored. As a weapon designer, and subsequently as a manager of such efforts, I discovered years ago that a sure way to raise the hackles of everyone within earshot is to suggest that someone's design was done in that particularly odd manner because it was considered "technically elegant" to do so. Designers become indignant, and upper management cringes, at the suggestion that something might have been done for reasons other than pure utilitarian engineering function. Nevertheless, the design culture in which an engineer works influences the nature of a design in ways that are not purely functional and utilitarian. This is true in the West more often than we would care to admit and it is equally true of our Soviet counterparts. That Soviet design culture is derived from its own engineering standards, specifications, and historical tradition and drives a Soviet designer just as surely as a Western designer is influenced by his own design culture. "Soviet oddities" have a realistic engineering basis within the Soviet design community that may not be readily observable to the uninitiated Western observer. Consider three items that are frequently commented on in Western literature as oddities: knobs and switches, metal, and gun calibers.

Western observers of Soviet equipment (particularly electronic equipment) often comment on how large and how widely spread out the control knobs and switches are. Words like "old-fashioned," "obsolete technology," and "crude" are frequently used because the Western observer comes from a design culture that believes small, high-density, and tightly packed are technically elegant and, therefore, beautiful. Soviet state-test specifications however, require that all equipment must be operated during qualification tests (the Soviet equivalent to OPEVAL) by personnel who are wearing regulation arctic gloves. A special test cycle is written into the test program to verify this procedure. But wait, a Westerner might say, this equipment is designed to go into a nuclear submarine, where it never freezes and where no one ever wears arctic gloves. The Soviet response might be, What about when the captain jumps down from the conning tower in the North Sea in an emergency with his arctic gloves on and tries to push a few buttons? What happens when he has to shut down the reactor for overhaul at Murmansk in January, discovers that the shoreline power cable has been cut, and has to restart everything while his submarine is frozen solid? The comment that the designer hears from the colonel in charge of the test is likely to be, Your equipment either passes the arctic glove test or it doesn't pass; we don't give waivers on that. Since getting equipment to pass state tests is considered technically elegant in the Soviet design culture, large well-spaced knobs and switches that can be handled while wearing arctic gloves are considered beautiful. Note also that most equipment panels in the Soviet Union are laid out by a human-factors engineering specialist. In this particular field of human engineering and psychology, the Soviets are considered to be ahead of the West.

Western observers who analyze Soviet equipment frequently note the softness and low strength of the metals used. Where the West would use high-carbon alloy steel, the Soviets use something that is softer and has less strength, even though its alloy content on analysis is often quite high. Why this difference in approach? Western engineers come from a design culture that places a premium on minimum weight and high strength levels. However, ordinary alloy steel goes through a crystalline transition point at -58°F. It becomes brittle and shatters like glass. Because the Soviets have had endless problems with this phenomenon, particularly in the colder regions of Siberia, they have developed a family of steels that don't have a crystalline transition point and retain their physical strength at cold temperatures, though they are somewhat softer and have a lower strength at room temperature. These alloys are used throughout Soviet industry and are readily available in the Soviet supply system. Designers of military equipment use these alloys not only because they are available, but also because it is considered technically elegant in their design culture not to have a part become brittle and shatter in the cold Soviet winter.

Western analysts find it strange that Soviet weapon designers do not continue the well-tried standard calibers for guns and ammunition but instead bring out an ever-widening variety of sizes with each new weapon introduced.[158] Although a strange practice by Western standards, the decision to use a new caliber for a new weapon is not the result of a whim, but rather is a carefully thought out policy with a long and interesting history.

> It was initiated by Stalin himself, a few hours before Germany's surprise attack on the U.S.S.R. It was on the eve of the war that the Soviet naval and coastal artillery were first issued the excellent 130-mm gun. This was subsequently used as an antitank gun and as a field gun and finally in a self-propelled variant. Also just before the war, in the spring of 1941, a highly successful rocket launcher was developed in the U.S.S.R. This was the BM-13, which could fire sixteen 130-mm rockets simultaneously. It later became known to the Soviet army as the 'Katyusha' and to the Germans as the "Stalin Organ." Naturally, the existence of both the gun and the rocket launcher were kept entirely secret.
>
> In the first days of June 1941, the new rocket launcher was shown to members of the Politburo in Stalin's presence. However, it was not fired, because artillery shells instead of rockets had been delivered to the test range. The mistake was understandable, in view of the great zeal with which secrecy was being preserved—how could the ordnance officers possibly have known of the existence of the 130-mm rockets, which bore no resemblance to artillery shells? Knowing Stalin, those present assumed that everyone responsible for this mistake would be shot immediately. However, Stalin told the Chekists not to get involved and went back to Moscow.
>
> The second demonstration took place on 21 June at Solnechnogorsk. This time everything proceeded very well. Stalin was delighted with the rocket launcher. Then and

158 Suvarov, p. 204.

there, on the range, he signed an order authorizing its issue to the Soviet army. However, he directed that, henceforth, in order to avoid confusion, the rockets should be referred to as 132-mm, not as 130-mm. Accordingly, while the rocket launcher continued to be known as the BM-13 (13-cm being 130-mm), the rockets were, henceforth, referred to, despite their true caliber, as 132-mm. That very night the war began.

During the war, projectiles of all types were fired in enormous quantities, reaching astronomical totals. They were transported for thousands of kilometers, under constant enemy attack. While they were being moved they had to be trans-shipped again and again and this was done by schoolboys, by old peasants, by convicts from prisons and camps, by German prisoners, and by Soviet soldiers who had only been in the army for two or three days. Orders and requisitions for the rockets were passed hastily by telephone from exchange-to-exchange and made all but inaudible by interference. But, there were no mistakes. Everyone could understand that "We need 130s" was a reference to artillery shells and it was equally clear that "1-3-2" meant rockets.

In 1942, the design of the rockets was modernized and their grouping capability and destructive effect were improved. In the process, they became slightly thicker, and their caliber was increased to 132-mm—thus coming to match their designation.[159]

Stalin's decision has been incorporated into Soviet weapon design culture: "Each time an entirely new type of projectile has been introduced, it has been given a new caliber."[160] The caliber-change issue is not controlled by technical/functional requirements, but by the influence of the design culture that produces the equipment.

The design culture of an observer produces an intellectual perspective that makes the equipment from another design culture appear technically strange, even if the perception is often subconscious. The caliber issue is one of the best examples of the difference in cultural perspective, for if "Western analysts find it hard to understand why the Soviet Union has constantly turned away from its old, well-tried standard calibers, Soviet analysts, for their part, wonder why Western designers stick so stubbornly to old specifications."[161] Consider how our system appears to "the Soviet analysts who sit and scratch their heads as they try to understand why it is that Western calibers never alter."[162]

Another aspect of Soviet weapon design philosophy that differs from the West's is the Soviets' adherence to an integrated-battlefield concept in weapon design. The Soviets neither plan for nor expect their equipment to perform as an isolated single unit on the battlefield; they expect their equipment to function as an integral part of a combined arms operation (obschevolskovol). This position is intellectually consistent with their highly centralized command-and-control system and planning for tactical operations. Equipment

159 Suvarov, p. 202.
160 Suvarov, p. 203.
161 Suvarov, p. 204.
162 Suvarov, p. 204.

is expected to operate as a part of an integrated unit, to perform a single limited operational mission[163] and only its given mission, and at the same time to be covered and supported by other items of specialized equipment doing specialized jobs. The Soviet belief is that the tactical effect of the whole, if properly integrated, is greater than the sum of the individual parts. [164] This tactical operations doctrine allows the Soviets to design their equipment on a single-mission basis, which is far different than the Western design policy that equipment should be capable of doing a wide variety of missions that it might be called upon to perform in combat. Almost all Western equipment is designed with a multiple-mission capability. The Soviet single-mission requirement permits designers to avoid complexity in their equipment and the functional compromise in design required to permit multiple-mission capability. This difference in design philosophy contributes to Soviet equipment being significantly less costly than its Western counterparts.[165, 166]

Yet another design factor that is influenced by Soviet military doctrine is equipment design life. The Soviets perceive that future wars, particularly on a tactical nuclear battlefield, will result in a high attrition rate for equipment.[167] They expect that the average life expectancy of a piece of equipment on the battlefield will be extremely short, and that the intensity of military operations and the density of fire will quickly destroy or wear out armament.[168] Soviet military equipment is therefore designed for a relatively limited operational life[169] rather than for protracted combat.[170] This presumption of a short operational life is reflected in various aspects of equipment design.

DESIGN METHODOLOGY

The Soviets use an evolutionary approach to equipment design,[171] in contrast to the Western approach of starting with a clean sheet of paper and designing an entirely new system from scratch, right down to the nuts and bolts. The Soviets prefer to take an

163 The methodology of combined arms warfare (obschevoyskovayaboyha) is beyond the scope of this document.

164 U.S. Department of Defense,1986, p. 47.

165 Desmond, p. 15.

166 Alexander, 1978, pp. 14-15.

167 Progress Publishers, *Marxism-Leninism on War and Army*, p. 220.

168 U.S. Department of Defense, 1986, p. 47.

169 Desmond, p. 21, William F. Scott, "Moscow's Military Industrial Complex," *Air Force Magazine*, 1989, p. 49, and Kehoe and Brower, p. 710.

170 Desmond, p. 20.

171 Alexander, 1978, p. 24.

existing design and modify it in an incremental manner, continuously improving on the earlier version.[172]

In Soviet terminology, this incremental system of design and development is called "design inheritance."[173] The philosophy is enshrined in Soviet textbooks as the approved method[174] and is embodied in the officially stated function of design bureaus: "The main function of design bureaus is to design and develop new experimental systems and to upgrade existing ones as proven technology becomes available."[175] Under this approach, "technological change and improved weapons result primarily from the process of cumulative product improvement and evolutionary growth."[176]

The design bureau takes an existing piece of equipment and improves it in increments,[177] incorporating new features and new technologies. After testing, the improved version is then improved once again. The design prototype model is at the heart of the system. The design team takes an existing production model, modifies it, then presents the model for state testing.[178] They then start the next stage of the cycle: taking that existing experimental model and modifying it again, incrementally adding more improvements. This process is similar to some commercial development approaches in the West, such as that used with automobiles, for example, where a new model with "improved features" is introduced each year.

To understand why the system works the way it does, one has to understand the institutional dynamics of the Soviet R&D management system that are driving the process. Soviet design bureaus, like everything else in the Soviet Union's planned economy, work on the basis of a plan that they are required to fulfill. If an enterprise fails to meet its plan requirement, even by a small margin, the enterprise's work force and management don't get their bonuses for meeting the plan.[179] In the case of an R&D facility, the bonuses are sometimes equivalent to 50% of the annual salary of the entire work force of the organization for the period of the plan.[180] In weapon-design bureaus, the plan normally encompasses a 2-year period and requires that the design bureau submit a prototype model for state testing at the end of that period.[181] Since the bonus involved is equivalent to 1 year's salary for everyone involved in producing the new prototype, no one ever fails to

172 Chakravrarty, p. 54.
173 Westwood, p. 30. Sometimes translated "design heredity."
174 Alexander, 1973, p. 431.
175 Desmond, p. 17.
176 Alexander, 1978, p. 24.
177 Westwood, p. 219 and p. 302.
178 U.S. Department of Defense, 1986, pp. 112.
179 Westwood, p. 190, and Amann and Cooper, 1986, p. 46.
180 Westwood, p. 57.
181 A substantial portion of the bonuses are awarded when the design prototype is submitted for the state test. The design team receives the balance when the design goes into production.

submit his prototype to state testing. It may be the old model with a new coat of paint, but it is always submitted. Failure to deliver a new model for state testing can cause a bureau's chief designer serious morale problems (since his employees do not get their bonuses) or worse.

The system of continuously producing prototypes has a number of advantages for the Soviets: technological advances can be assimilated in small increments, thus avoiding the uncertainties of large jumps in technology.[182,183] The design risks associated with the introduction of new technologies are significantly reduced.[184] At the same time, the prototype construction and operational testing provide information on the costs of producing and operating the new weapon, in turn reducing the cost risks inherent in the decision to put the new system into production.[185]

The multiplicity of prototypes also enables the Soviets to take a long-range view of defense equipment development.[186] There is no urgent reason to incorporate a given new technology or capability in the present model; they can instead wait and add the latest technological bells and whistles to the next prototype model.[187] "The Soviet designer (can) design each model to single mission requirements; the complications of incorporating growth capacity and multiple-mission capability are not required in the initial production models."[188] He knows that he will be able to add these features later.[189] In fact, "Seldom is more than one new technology used in a new or upgraded system."[190] This model-based system helps to keep changes to a minimum to avoid disrupting production lines, a strong point from the perspective of the Soviets' production bureaucracy.[191]

This system of continuous, evolutionary, prototype development has two beneficial effects on the Soviet R&D bureaucracy. First, it "leaves the defense industries' research institutes and design bureaus relatively independent of production trends and much less affected by cyclical ups and downs than their American counterparts. This institutional stability results in a regular progression of designs and prototypes, as well as in a level and quality of experience that only comes from the actual creation and test of new ideas in working hardware.[192] Second, it permits development to be run as "a business unto itself,

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182 U.S. Department of Defense, 1986, p. 112.
183 Alexander, 1973, p. 431.
184 Desmond, p. 20.
185 Murray and Viotti, pp. 176-177.
186 Dunlavey, p. 3.
187 U.S. Department of Defense, 1986, p. 112.
188 Westwood, p. 314.
189 U.S. Department of Defense, 1986, p. 112.
190 Desmond, p. 17.
191 Murray and Viotti, p. 168.
192 Murray and Viotti, p. 169, and Alexander, 1978, p. 25.

rather than . . . for the short-term objective of getting a follow-on production program,"[193] as is often done in the U.S.

A noteworthy aspect of the Soviet prototype-development process is that it is done competitively.[194] In the Soviet consumer economy, people are seldom given more than one choice, and there is no product competition. The Soviet military, however, likes to have a choice of models to pick from, so they often introduce competition at the design level by assigning two or more design bureaus to develop essentially the same equipment in competition with each other.[195,196] The development of military equipment is usually assigned to a design bureau that is a specialist in that type of equipment.[197] The Soviets generally keep at least two design bureaus in each major weapons field (in some of the more exotic fields there is only one), and competition between bureaus often results in a good deal of friendly (and sometimes not so friendly) rivalry.[198] Competition is often carried through the prototype-development stage and into actual competitive trials in state testing.[199] This practice results in a spirit of competition between the design teams, a spirit that might be described as professional rivalry[200] and that acts as a significant motivating force to the technical personnel involved.

Parallel development of equipment through competition between design bureaus, when combined with evolutionary development through prototyping, gives the Soviet military-equipment buyers a much greater choice than is customary in the Soviet economy,[201] or probably than is available to their counterparts in the West. The wide availability of models to choose from also increases the probability that the Soviet military will find a highly functional piece of equipment that meets its needs and requirements[202] and "increases the likelihood that an acceptable version becomes available for deployment."[203] When coupled with the relatively stable budgets of R&D organizations, this approach produces a continuous stream of new weapons embodying current technology and increased performance.[204] Each model may be only slightly better than the

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193 Gansler, p. 251.
194 Amann, Cooper, and Davies, p. 317.
195 Westwood, p. 142.
196 Holloway, *The Soviet Union and The Arms Race* (New Haven: Yale University Press, 2nd ed.), p. 142.
197 Robert A. Magnan, *In Search of the "End Game:" A Comparison of U.S. and Foreign Weapons Acquisition Systems*, a study conducted under the DCI Exceptional Intelligence Analyst Program, undated (early 1970s), unpublished, p. 49.
198 Magnan, p. 49.
199 Holloway, p. 142.
200 Magnan, p. 49.
201 Amann, Cooper, and Davies, p. 319.
202 Gansler, p. 251.
203 Murray and Viotti, p. 177.
204 Murray and Viotti," 1982, p. 177, and Alexander, 1979, p. 28.

one before it, but the product line becomes very much better over several generations.[205] The approach also provides the Soviet decision-making bureaucracy with a means of reducing the uncertainties of technological development, performance, and cost of new weapon systems.

The Soviets emphasize an evolutionary approach to weapon system and equipment development, whereas the U.S. (and the other Western nations) prefer a revolutionary design approach.[206] This is even truer at the component level, as the West tends to start afresh with an "all-new" weapon system that includes an all-new set of specialized components.[207] Such an approach is quite rare in the Soviet system (through the Soviets have done it). The Soviet approach is characterized by "common use of subsystems, components and parts . . . ."[208] using off-the-shelf components and subsystems of proven reliability that are already in the supply and production system. The Soviets develop components by the same evolutionary methodology used for weapons as a whole. Of the 300-plus design bureaus in the Soviet Union, only 50 are oriented to weapon systems output; the remainder are component- and subsystem-development organizations.[209] These organizations are not building weapons per se, but rather developing the subsystems and components to go into the weapons. There are design bureaus working on aircraft engines, radars, and tank guns. These subsystem- and component-development efforts are conducted independently of any particular system or program, and the goal of these bureaus is to produce a better subsystem independent of any identifiable system requirement. The job of each bureau is to build a better mousetrap through the evolutionary prototype system, and this task is sometimes carried out competitively.[210]

The systems-development organizations incorporate the newly developed components and subsystems into a new generation of equipment. The Soviets like to improve the characteristics of their systems sequentially,[211] and it is unusual for more than one new major subsystem or technology at a time to be incorporated in a weapon system.[212]

Once a subsystem or component is accepted, it is treated as a standard item and used throughout the Soviet system. This "multiple use of subsystems, components, and parts across equipment of the same vintage, together with repeated use of the same subsystems in succeeding generations, is another typical feature of Soviet weapons

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205 Friedman, pp. 66-67.
206 Chakravarty, p. 49, and Amann, Cooper, and Davies, p. 277.
207 Desmond, p. 20.
208 Alexander, 1978, p.18.
209 Long and Reppy, p. 143.
210 Magnan, p. 52.
211 Chakravarty, p. 50.
212 Desmond, p. 17, and Alexander, 1973, p. 430.

development."[213] "Institutionalized component commonality"[214] has been formulated as a "self-conscious design philosophy"[215] that minimizes development risk[216] and logistical problems and reduces the production risk in an economy where distribution, availability, and variety are major problems.[217]

The Soviets believe that commonality of components has other institutional advantages, as can be seen from the following quote from a member of the Tank Industry Commissariat: "The experience of the war shows that the design process ensures rapid introduction into series production only when it is based on assemblies which have been mastered earlier. Consequently, the continuous improvement of the basic assemblies is essential. To design a new tank, while at the same time creating new assemblies, means, as a rule, passing on for series production an uncomplicated tank."[218] While this belief runs contrary to the system design approach of the West, the Soviet component design methodology is very close to the United States R&D method in use before the weapon-system development concept was introduced in the 1960s.[219]

Hand in hand with commonality is the Soviet position on standardization. The Soviet Union is an ideological state whose ideology was developed in the early stages of industrial civilization as a response to problems and social stresses caused by the transition from an agricultural to industrial society. The Soviet Union considers itself even today primarily an industrial "workers' state" and runs its society on an "industrial basis." This leads the Soviets to a strong belief in standardization and central planning.

The Soviets believe that the philosophy of central planning will enable them to overtake and economically supplant the West. The Soviets believe that through central planning they can optimize the distribution of goods and services to the population as a whole. The handmaiden of this philosophy is an emphasis on standardization that can only be regarded as fanatical by Western standards. To achieve standardization, the Soviets have developed a pervasive system of national standards for use in the industrial sector of the economy. These standards are called "State Standards" or GOST (for Gosudarstvennye Standarty)[220] and operate much like Military Standards do in the United States, except that the GOST apply to all industries, not just the defense sector. These standards "have legal status in their own right . . . they automatically form a legal framework for purchasing

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213 Alexander, 1978, p. 9.
214 Westwood, p. 301.
215 Holloway, p. 147.
216 Westwood, p. 304.
217 Westwood, p. 304.
218 Long and Reppy, p. 150.
219 Merton J. Peck and Frederic M. Scherer, *The Weapons Acquisition Process: An Economic Analysis* (Boston: Harvard University, 1962), pp. 27-31.
220 Amann and Cooper, 1986, p. 99.

contracts between Soviet enterprises, as well as carrying penalties for nonobservance."[221] "There are standardization monitors in research centers, design bureaus, production plants, and at the national level."[222] The GOST and their application are discussed in some detail in the section titled Military Research-Production Cycle (below).

The Soviet passion for standardization permeates the entire society and extends even to the level of children's piano lessons. Standard state-approved piano lessons have been developed by the piano curriculum department of the state music education authority in Moscow for use by all piano teachers throughout the Soviet Union. All other curricula have been outlawed and teaching nonstandard piano lessons has been made a criminal offense.

Commonality of parts offers several advantages. "The standardization in Soviet weapon systems appears to reduce system development risk and improves producibility and reliability."[223] Therefore, "Soviet weapons are designed as far as possible using off-the-shelf components. Soviet designers appear even to accept performance penalties when standardized parts cannot provide the desired performance,"[224] Something that almost never happens in the West where performance is considered the "God of design." By contrast, "the American 'all-new' weapon system idea eschews standardization in favor of specialized components."[225] This is not to say that Soviet designers always adhere rigidly to state standards; they do on occasion demand and get parts that differ from the ones provided for in the Soviet state standards.[226] In this they differ from Soviet civilian industry, where a proposed product presented for deployment to production "would be immediately rejected by the producer if nonstandard parts were stipulated where standard ones could be used."[227] But the emphasis on parts standardization is still much greater than in the West, and a Western industrial designer would find the Soviet emphasis on standardization restrictive.[228]

The Soviet philosophy on commonality of components between systems and even between different generations of equipment affects their attitudes toward reliability. The Soviets believe the way to achieve high reliability is to use parts and components of known high-reliability history, whereas the Western practice is to design reliability into the parts

221 Amann and Cooper, 1986, p. 99.
222 Desmond, p. 20.
223 Kehoe and Brower, 1982, p. 709.
224 Kehoe and Brower, 1982, p. 709.
225 Desmond, p. 20.
226 Agursky, p. 11.
227 Agursky, p. 11.
228 It is the author's opinion that the West does not do enough standardization at the parts level. This is an area where the Soviets are definitely ahead of the West.

and components through advanced analytical means.[229] The Soviet position has a great deal to be said in its favor.

While the evolutionary development methodology must be regarded as the Soviets' standard, it cannot be said that the Soviets never start from scratch and design a wholly new weapon system. The Soviet system has a procedure for a class of weapons called "new in principle,"[230] which is used for the development of equipment having no precedent,[231] or when major technological change occurs between one generation and the next.[232] Nuclear weapons and ICBMs were both developed by the Soviets using this methodology, and one might expect that high-energy lasers for the Soviet "star wars" defense system are being developed by this method. In such high-technology areas, the use of tried-and-tested existing subsystems, no matter how desirable, may not be possible.[233] These development cases, through rare, follow an approach similar to the American systems-development approach and makes effective use of newly developed subsystems.[234] These "all new-in-principle projects are affected by fewer constraints than established programs."[235] When the new activity achieves a sufficient level of continuity and maturity, a conventional ministerial design setup is established to carry on the work,[236] as has been done in the case of ICBMs.

The fact that "American weapons development . . . goes for order of magnitude improvement and all-around improvement,"[237] while the Soviets improve the characteristics of their equipment one-by-one, through sequential modification in an evolutionary manner,[238] does not make Soviet R&D methodology less effective than its Western counterparts. In fact, the Soviet 's methodology has, in the author's opinion, a great deal to recommend it. The Soviets have tailored their weapons-development system to their industrial capabilities, technical proficiencies, and economic infrastructure; by so doing, they have developed a weapon system design philosophy that works well for them.[239]

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229 Desmond, p. 20.
230 Murray and Viotti, pp. 176-182.
231 Murray and Viotti, 1982, p. 178.
232 Holloway, p. 148.
233 Holloway, p. 148.
234 Alexander, 1978, p. 24.
235 Murray and Viotti, p. 178.
236 Alexander, 1978, p. 34.
237 Chakravarty, p. 50.
238 Chakravarty, p. 50.
239 Dunlavy, p. 2.

MILITARY RESEARCH-PRODUCTION CYCLE

"One of the great flaws of Western analysis of the Soviet army is the ever-present tendency to 'mirror image,' to assume that the Soviets do or perceive things in the same way as Western armies. This applies especially to Soviet weapons strength and policy . . . It is therefore incorrect simply to perceive Soviet equipment policy as a mirror of a Western model."[240] Nowhere is this observation truer than in the weapon-development cycle. Many Western observers say that "because a country's weapons-acquisition system is mostly determined by physical laws . . . that dictate how to get from A to Z in developing a weapon [the process is] essentially the same in all systems."[241] The statement is generally followed by a discourse, using diagrams and Western (largely U.S.) terminology, to demonstrate that the Soviet system of weapons development is essentially the same as the American system. If this is true, why bother to study the Soviet weapons-acquisition system when all one has to do is read DOD 5000.1 (which outlines the U.S. weapons-acquisition system)? If one approaches the subject with this mind set, one will miss the characteristics that distinguish the Soviet system from ours and will spend all one's time pushing data into preconceived mental boxes.

The most significant problem with the mirror-image theory is that it is not correct, and nowhere is this tendency to "mirror image" the Western approach less valid than in the Soviet weapon-development process. Even the basic concept of the "development process" is different. By that phrase Westerners mean an engineering methodology needed to develop an item, or the RDT&E cycle by which Department of Defense directs research efforts into the basic laws of science, then directs that technical knowledge into developing a useful piece of equipment, then tests and evaluates that piece of equipment for use in the field. The Soviet Union, on the other hand, speaks of a "military research-production cycle"[242] that uses engineering technology to develop and test a weapon and put it into production. The differences between the Soviet and American systems run deeper than mere words; the Soviet military research-production cycle has several stages and requirements that the American RDT&E process does not have, and the American process has a couple of stages that the Soviet cycle does not have.

Westerners have three major perceptual problems in understanding the Soviet system. First, by "development process" Westerners mean both the methodology of how one develops a machine and the stages in the RDT&E cycle. This creates a translational or semantic problem. When a Soviet speaks of the development or design process he means the engineering methodology of developing a system, which is the evolutionary methodology and system of design inheritance discussed in the previous section. He does not mean the "military research-production cycle." To the Soviets, the development process

240 Isby, p. 28.
241 Magnan, p. 7.
242 Amann, Cooper, and Davies, p. 354.

and the military research-production cycle are two distinct and different activities; the lack of precision in translation creates confusion in Western literature.

Second, the Soviets place emphasis on the production end of the cycle. Where the West sees RDT&E as a method to reach a goal, that goal is only to pass the test-and-evaluation process. The Soviets, on the other hand, see their goal as getting the system successfully into production, and so three formal phases exist in the Soviet process that have to do with the transition to production and that are not even addressed in the Western framework. The Soviet emphasis on production and production engineering in the early stages of the development process is quite strong by Western standards.[243]

Third, the Soviet military research-production cycle does not include research work as it is understood in the Western phrase "research and development." Both basic research (fundamental'noye issledovanie) and applied research (priklanoye issledovanie) are conducted outside the development (razrabotka) cycle.[244] Basic and applied research are conducted in Scientific Research Institutes (NII),[245] which research basic scientific phenomenon and develop advanced technology.[246]

Most military ministries have a set of research institutes that work on areas and subjects of interest to the ministry. For example, the Ministry of Aviation has six research institutes.[247] This group is headed by the Central Aerohydrodynamics Institute (TsAG), which is the oldest and most important aviation research institute in the Soviet Union[248] and which acts as the Ministry's central research institute for aviation technology. This central research institute is in turn supported by other, more specialized, research institutes working on specific aspects of aviation problems.

The Soviet Union has two types of research institutes. One does "scientific research work" (NIR), which has the function of proof-of-concept and/or the demonstration of technical feasibility. The other does "experimental technological work" (OTR), which has the function of developing materials and production technologies needed to effectively build an item.[249] For example, the Ministry of Aviation has an "All Union Institute of Aviation Material" (UIAM), which develops material and works on material-related problems for the aviation industry; and, a "Scientific Research Institute of Aviation Technology and Production" (NIAT), which works on the development of production technology and on

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243 The Soviet emphasis on production in the development cycle has a number of desirable results. This area, one of the major strengths of the Soviet weapon-development processes, is one in which the West could learn something from the Soviets.

244 Westwood, p. 204.

245 Westwood, p. 149.

246 Westwood, p. 204.

247 Alexander, 1973, p. 427.

248 Alexander, 1973, p. 427.

249 Westwood, p. 203.

manufacturing problems.[250] Some of these production technology research institutes are huge and dwarf anything of their kind in the West. The Paton Welding Institute [251] in Kiev, for example, has several thousand employees and in and of itself makes the Soviet Union the world's leader in welding technology.

The research institutes are funded independently of production or development programs.[252] They are in the business of advancing technology and are funded to conduct applied research in their area of expertise (quite different from the West, where "much basic research is financed by defense departments and related agencies"[253]). The independence of research institutes has two significant consequences. First, it tends to insulate and free the Soviet research system from the up-and-down financial problems that affect Western military research.[254] Second, "since development programs are not the way in which funds are acquired for applied research, the institutes have no incentive to press fancy technology on the designer of a weapon to get funds for their research."[255]

Research institutes collect their research findings and publish them in official handbooks. These handbooks for designers are the chief vehicle for the transmission of research results to the design community. Sections of the handbook are written by leading research scientists and are intended to keep the design bureaus abreast of the latest research results.[256] These handbooks provide authoritative guides to the design bureaus on a wide range of matters.[257] For example, the TsAg publishes a handbook of approved aircraft structures and aerodynamic forms,[258] and "handbooks on approved materials and production techniques are issued by the NIAT."[259]

The handbooks transmit to the design bureaus technology that they can use in building their systems. The handbooks also constrain a design bureau, since it can only use in its design the process technology and material laid down in the ministries' research institutes' handbooks.[260] The fact that only central-research-institute-approved technologies and techniques[261] can be incorporated in a design leads to "certain similarities in approach" from one design bureau to another.[262]

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250 Alexander, 1973, p. 428.
251 *Business Week*, November 7, 1988, p. 83.
252 Amann, Cooper, and Davies, p. 318.
253 Amann, Cooper, and Davies, p. 318.
254 Murray and Viotti, p. 83.
255 Amann, Cooper, and Davies, p. 318.
256 Alexander, 1973, p. 427.
257 Desmond, p. 17.
258 Alexander, 1973, p. 427.
259 Alexander, 1973, p. 428.
260 Leebaert, p. 282, and Alexander, 1973, p. 428.
261 Westwood, p. 302.
262 Alexander, 1973, p. 427.

Controlled use of technology is one of the major philosophical differences between the Western R&D cycle and the Soviet military research-production cycle. Westerners see their R&D system as a means of investigating the fundamental laws of nature (research) and applying the results to the needs of humanity (development). The Soviets see their system as a means of applying existing technology (as defined by the research institute handbook) to develop a system useful to humanity (development, pure and simple) and deploy that system effectively (production).[263] In short, the Soviet military research-production cycle is a methodology used to deploy existing technology.

The steps and sequence that a Soviet military system goes through as it is developed and produced are readily available for study in the West because the research-production cycle is essentially the same in the civilian and military industries.[264] The process is controlled by the single integrated system of "State Standards of the U.S.S.R.," collectively referred to as the "Unified System for Machine Design Documentation." [265] This system consists of four subsystems or series of state standards, the GOST standards,[266] as follows:

1. The Unified System of Design Documentation (GOST Series 2.XXX, published in 1968), identified by the acronym YeSKD
2. The Unified System of Technological Preparation for Production (GOST Series 14.XXX, published in 1973 and 1974), identified by the acronym YeSTPP
3. The Unified System of Technological Documentation (GOST Series 3.XXX, published in 1974), identified by the acronym YeSTD
4. The Unified System of Product Development and Hand-Over to Production[267] (GOST Series 15.XXX, published in 1982), and identified by the acronym SRPP

263 Amann, Cooper, and Davies, p. 318, and p. 323 and Leebaert, p. 282.

264 Agursky, p. 23, and Amann, Cooper, and Davies, p. 294.

265 The Soviet military program-manager's handbook is unclassified and freely available, but few in the West read it.

266 The term GOST is an abbreviation of GOSTANDART, which itself is a contraction of gosudarstvennye standarty (state standard).

267 Sometimes translated as "Unified System of Development and Placement of Products into Production."

These interrelated standards form the core of the Soviet development and transition-to-production methodology. The interrelationship is illustrated in the system's Soviet logo (Figure 3). These state standards are in turn supported by other systems of standards,[268] such as the Unified System for State Control of Product Quality (YeSG UKP) and the State System for Ensuring Identical Measurements (GSI, the metrology standards).

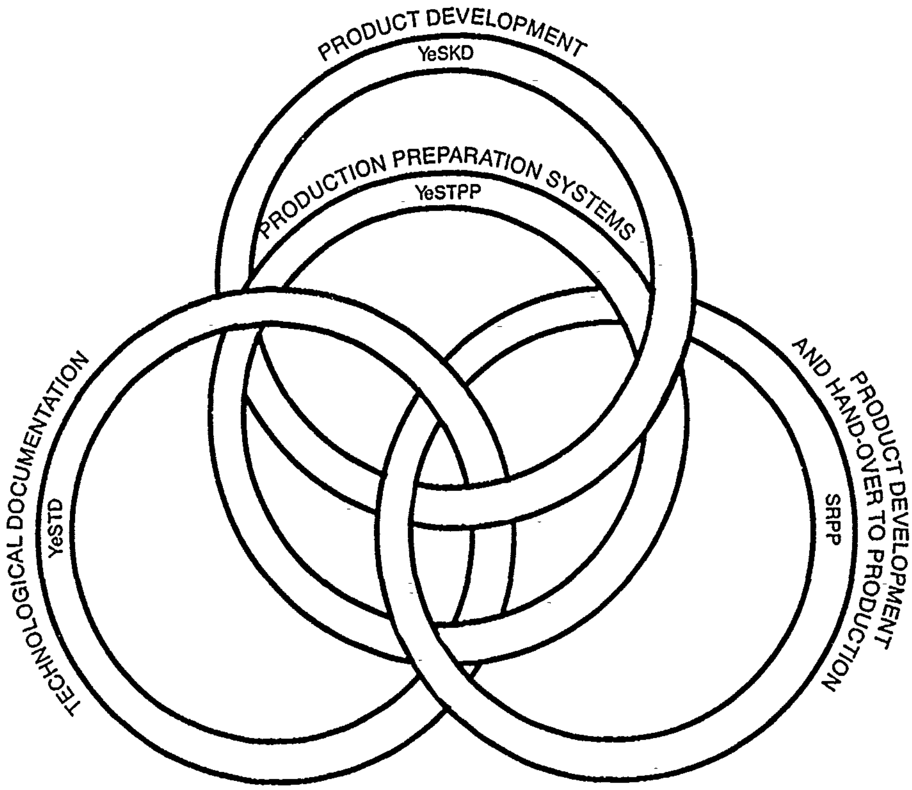

FIGURE 3. Logo of The Soviet Standards Society

The Soviets consider the Unified System of Technological Preparation for Production, the YeSTPP, as the master, or controlling, system. Note its central location in the Soviet Standards Society's logo.

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268 The comprehensive Soviet system of state standards applies throughout industry and is used to manage the entire economy. In 1982 there were over 23,000 state standards in the Soviet system. These standards were divided into 31 series in the Index of State Standards issued at the beginning of the twelfth 5-year plan in 1986. This is up from 20 series listed in the 1982 index, a result of the changeover in series arrangement at the start of the 1986 5-year plan—some of the numbers of individual standards changed. A large number of sequentially numbered technical GOSTs exist outside of the series. The standards that are issued in series bear a GOST number in the form (XX.XXX-YY); the nonseries standards have a GOST number form XXXXX-YY.

The sequence of steps in the research-production cycle is controlled primarily by the Unified System of Design Documentation, YeSKD,[269] which describes a development-production process consisting of nine steps, four decision points, and outside inputs. An outline of the research-production cycle is shown in Figure 4.

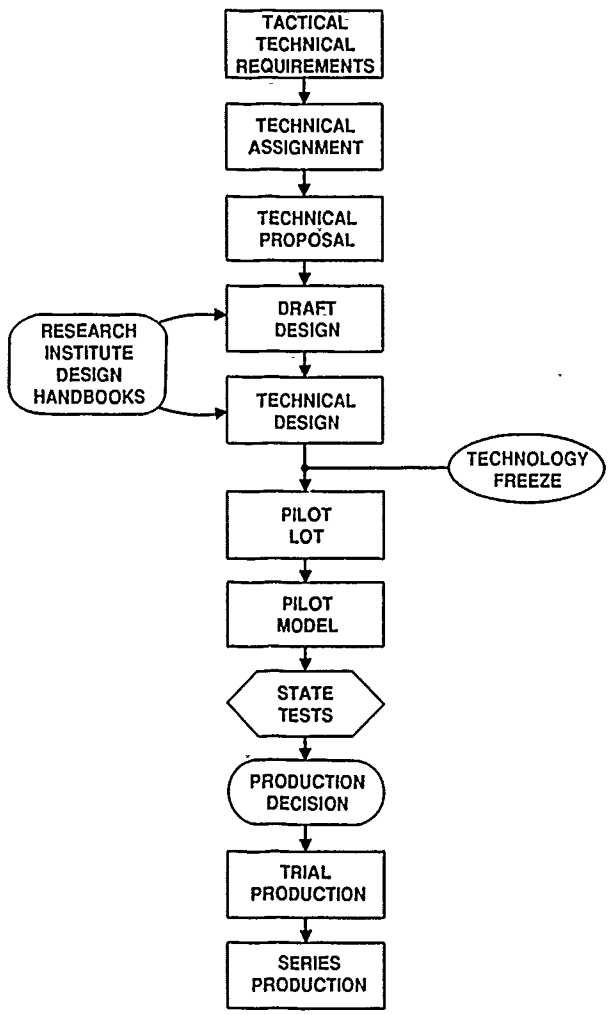

FIGURE 4. Soviet Research-Production Cycle.

269 The stages of design are specified in GOST 2.103-68, Unified System for Design Documentation: Stages of Design, which is the controlling document of this series.

The process starts with a preproject phase that generates requirements. The services' armament directorates[270] deal directly with the defense production ministries in establishing requirements.[271] The requirements-generation phase appears to be a fluid process with a great deal of give-and-take between the military, defense production ministries, scientific research institutes, and design bureaus. The participants discuss possibilities, weigh alternatives, and make trade-offs. What emerges from this process is a preproject tactical-technical requirements document. This is not a complicated document; it does, however, describe the purpose of the system, tasks and conditions of operation, performance characteristics, and the relative importance of the various requirements.[272, 273]

The next phase in the development-production cycle is the technical assignment (tekhnicheskoye zadaniye). The function of this phase is to generate a final requirements document known as the tactical-technical instruction or TTZ,[274] which is prepared by the military customer's technical administrator in conjunction with the military production ministry and the scientific research institutes (including, on some advanced systems, the Soviet Academy of Sciences), with inputs from the design bureaus. The TTZ sets out the object and purpose of the development: the tactical, technical, technical-economic, economic (i.e., cost goals), operational cost, and other special requirements for the development.[275,276]In addition, all military equipment must meet certain general requirements, and these technical "boiler plate" requirements are incorporated into every new development instruction.[277] The TTZ is used by the military technical administrator as the basis for monitoring the development effort,[278] as well as for testing later in the cycle.[279]

The next phase is the technical proposal. In this phase, the TTZ is sent to the design bureaus. The design bureaus review the document and prepare technical proposals for systems and equipment to fulfill its requirements. The Soviet practice is to give this same

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270 The Soviet Union has five military services: Strategic Rocket Forces, Ground Forces (Army), National Air Defense, Air Force, and Navy.

271 Desmond, p. 16.

272 Alexander, 1973, p. 429.

273 Western requirement documentation generally sets hard minimum performance goals early in the concept stage and does not give guidance on the relative importance of parameters. In this regard the Soviet system appears more flexible in the early stage than its Western counterparts.

274 The contents requirements of these documents are contained in GOST 2.114-70, Technical Requirements: Rules for Construction, Tryout, and Formation.

275 Amann, Cooper, and Davies, p. 324.

276 Gansler, p. 279.

277 Agursky, p. 9.

278 Amann, Cooper, and Davies, p. 324.

279 Amann, Cooper, and Davies, p. 324.

assignment to two or three design bureaus and have them develop competitive designs.[280] "This (system of competition) gives the customer a degree of choice unusual in the Soviet economy."[281] This competition between design organizations might better be described as professional rivalry or empire building,[282] but it does invigorate the Soviet design organizations with a degree of competitive motivation that is lacking throughout the rest of the Soviet industrial economy. It also "serves to make the designers more innovative and responsive to the demands of the customer."[283] The competition most often ends at the paper design stage, although competition is sometimes extended through the prototype development and testing stage and in some cases even into production, resulting in the building of apparently redundant systems.[284, 285]

The function of the technical-proposal phase and its varying degrees of competition is to develop a technical proposal for a system.[286] This proposal is prepared by the design bureau's chief designer and a small team of highly experienced senior personnel.[287, 288] This technical proposal is generated in a surprisingly short period of time by Western standards: usually 6 weeks or less.[289] The proposal is then sent to a review community composed of customer representatives, ministry personnel, and personnel from the central institute of the subject involved.[290] This review process may be of several iterations, and it continues until the review community selects one or more designs for development.[291] The technical proposal outlines both the designs being proposed and the resource requirements needed by the design bureaus for the system's development.[292]

The development of the technical proposal is considered by the Soviets to be the first stage of the formal evolution of a system's design documentation. The proposal is developed in accordance with the principles of the YeSKD, which requires all stages of

280 Magnan, p. 49, and Holloway, p. 142. While competition between design bureaus is common, it is not universal, even on large systems such as missiles and aircraft. In some cases, a design bureau is selected directly because of its specialty and expertise to satisfy a particular military mission requirement.

281 Amann, Cooper, and Davies, p. 319.

282 Magnan, p. 49.

283 Amann, Cooper, and Davies, p. 317.

284 Amann, Cooper, and Davies, p. 319.

285 Holloway, p. 142.

286 The format and technical requirements are specified by GOST 2.118-73, Technical Proposal.

287 Alexander, 1973, p. 429.

288 Westwood, p. 315.

289 Westwood, p. 151.

290 Westwood, p. 151.

291 Westwood, p. 151.

292 Cochran, Arkin, Norris, and Sands, p. 95.

design to be documented separately.[293] The project documentation generated at this stage of development is assigned the letter "P."[294]

The next phase in the Soviet cycle is the development of the draft design,[295] which is done by a small team of about 20 experienced designers assisted by senior specialists in related fields.[296, 297] This team prepares a more detailed development of its design concept over a period of about 6 months [298,299]

In the draft-design phase the research institutes' handbooks, discussed earlier, come into play; the designers must use only tested and proven technology that is contained in the handbooks.[300, 301] In this way, the design bureau, when it starts work on a new system, draws on state-of-the-art technology as it is defined by the handbooks.[302] These "handbooks prevent the design bureaus from incorporating into their design new technologies that have not yet been tested, proved, and approved."[303] Special permission must be obtained to incorporate new and unproven technology into a design.[304] The Soviets view design as the application of existing technology to meet a given requirement, and in this light the Soviet designers turn to the research institutes and take what is available, rather than wait for something new. Furthermore, since development programs are not the means by which funds are acquired for applied research in the Soviet Union, there is no incentive to use sophisticated new technology in designs.[305] The handbooks "constrain the designers to work within a common, proven technical code. The emphasis on the use of handbooks in the design process leads to certain similarities in approach from one design bureau to another."[306] The procedure is not as negative as it sounds, because Soviet designers are required by law to evaluate alternative system concepts at this stage of the design cycle.[307]

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293 Westwood, p. 300.
294 GOST 2.103-68.
295 The requirements for the draft design are specified in GOST 2.119-73, Draft Design.
296 Alexander, 1973, p. 429.
297 Westwood, p. 315.
298 Alexander, 1973, p. 429.
299 Westwood, p. 315.
300 Desmond, p. 17.
301 Because of the constraint, this phase is sometimes referred to by Western analysts as the first technological freeze point.
302 Amann, Cooper, and Davies, p. 318.
303 Alexander, 1973, p. 428.
304 Scott and Scott, p. 49.
305 Holloway, p. 142.
306 Alexander, 1973, p. 427.
307 Desmond, p. 22.

This draft-design phase of the development starts what the Soviets call "experimental design work" (OKR).[308] A program's priority is assigned at the outset of this phase,[309] and that priority assignment determines the availability of such things as wind tunnels, materials, and computer time.[310] There are three levels of priority: critical, vital, and secondary. Assignment to one of these priorities requires that project work be handled in its corresponding "mode of procedure" as shown below.

Priority of Task	Mode of Procedure
Critical	Accelerated
Vital	Normal-Vital
Secondary	Normal-Secondary

The modes of procedure require the commitment of resources in the following manner:[311]

1. Accelerated: development of the system in the shortest possible time that achieves required effectiveness with minimum, but unconstrained, resource outlays. This mode is reserved for a few exceptional cases.

2. Normal-Vital: development of the system with the stated required effectiveness according to the normal schedule with minimum, but unconstrained, resource outlays. This is the basic and usual mode of operation.

3. Normal-Secondary: development of all remaining systems to achieve highest overall effectiveness according to normal schedule. This mode is applied to all remaining non-urgent systems developments.

A priority in the Soviet system gives the program claim on all necessary (but not excessive) resources and inputs. Consequently, some low-priority projects can languish for years in an ongoing yet uncompleted status.[312]

In accordance with the YeSKD, all documentation generated during the draft-design phase of development is assigned the letter "E."[313] The draft designs are analyzed by the customer's review committee, and a set of proposals and recommendations is collected and sent back for the further guidance of the designers.[314]

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308 Westwood, p. 302.
309 Westwood, p. 151.
310 Westwood, p. 151.
311 Westwood, p. 148.
312 Westwood, p. 151.
313 GOST 2.103-68.
314 Leebaert, p. 278.

The next phase of the Soviet development-production process is the technical-design phase.[315, 316] The detailed technical work is completed during this phase, and development efforts can take several years. A large staff of engineers and technical specialists convert the senior designer's concepts into semidetailed drawings.[317] In this effort, the technical design staff is again guided by the research institutes' handbooks as well as by numerous state standards and regulations.[318] These guides encourage commonality and the use of standardized parts and subsystems.[319] They also tell the designer which proven components may be incorporated and specify appropriate manufacturing techniques and materials to be used.[320] By incorporating standard interfaces into the design at this point, the designer can often extend competition to the subsystem level.[321, 322] The Soviets, as noted earlier, use a conservative evolutionary methodology in design development that permits only a very selective introduction of new technology into a system;[323] seldom is more than one new technology used in a new or upgraded system.[324] Since design technology is fixed by the handbook, design problems are solved by more clever use of existing technologies rather than by new technological developments.[325]

During the technical-design phase, the Soviet system of transitioning an item into production makes its first real impact.[326] "Every design team has a standards section. This group examines the design to determine whether all state and industry standards are adhered to, whether off-the-shelf items can be used instead of newly designed equipment, and whether standardized tooling can be used in production." [327] In addition, a production engineering staff assigned to the team reviews the preliminary design drawings and makes inputs to the design to ensure its producibility.

The Soviets recognize that constant input of new technology can produce significant perturbations both in the development of a system and in production. To combat this problem, and recognizing the tendency of designers to incorporate the latest technology into their designs, the Soviets do something quite different from the West; at the end of this phase, when the technical design is accepted, they issue a formal freeze on the technology

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315 GOST 2.103-68.
316 The requirements are specified in GOST 2.120-733, Technical Design.
317 Desmond, p. 22.
318 Gansler, p. 253.
319 Amann, Cooper, and Davies, p. 318.
320 Desmond, p. 17.
321 Alexander, 1973, p. 430.
322 Magnan, p. 52.
323 Dunlavy, p. 5.
324 Desmond, p. 17.
325 Westwood, p. 303.
326 In theory, this process started at the previous stage, but its effect was minimal.
327 Alexander, 1973, pp. 430-431.

to be incorporated into the system.[328, 329, 330] After this point, high-level permission is required to incorporate new technologies into a design, and while it probably can be done, it is regarded as an abnormal way of doing state business.[331] The technology freeze encompasses the entire system, including the processing technology developed to support the manufacturing of the system. This processing technology is being developed under YeSTD in parallel with the design of the system. Thus, the manufacturing technology to be used to make the system is, in effect, also frozen at the end of the technical-design phase. Documentation generated during the technical-design phase is assigned the letter "T."[332]

The next phase of the Soviet development cycle is loosely translated in the West as the prototype-development stage. The Soviets actually consider this as two separate stages: the pilot-model and the pilot-lot phases.

After acceptance of the technical design, the design bureau starts development and construction of a pilot model. Prototype units (either pilot models or pilot lots) are built either in the design bureau's prototype-construction shops[333] or in "a special experimental plant associated with and under control of the design bureau."[334] In this phase, the design bureau's engineering staff produces rough engineering drawings.

> As the engineering drawings are produced, they are sent to the prototype shops where the prototype is constructed. In these drawings, only the most critical or complicated assemblies and technological processes are specified in detail. The prototype plant is manned by highly skilled machinists working general-purpose machines. Consequently, they are able to work from relatively unfinished drawings, saving the time that would be needed for production drawings and specially designed tools.[335]

Nevertheless, prototype design and construction methods are regulated by the technology handbooks of the research institute concerned with production technology and materials.[336]

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328 Westwood, p. 154.

329 Westwood, p. 79.

330 It is the Soviet position, under the evolutionary development philosophy, that new technology can and should be easily incorporated into the next model that will be coming along shortly rather than upsetting the current design model's progress.

331 It is technically illegal to vary from the specified development procedure in the Soviet Union because the state standards, including the "Unified System of Design Documentation" (YeSKD), are propagated as decrees of the Council of Ministers of the U.S.S.R., "The non-observance [of which] is proscribed in accordance with law." (GOST 2.103-68).

332 GOST 1.103-68.

333 Alexander, 1973, p. 427.

334 Alexander, 1973, p. 428.

335 Alexander, 1973, p. 429.

336 Desmond, p. 22.

This first pilot model is used primarily as a learning tool by the Soviet design team. Based on the experience acquired in building the pilot model, Soviet engineers modify their design drawings. At this point, the pilot model is often put through an extensive program of factory tests to "prove it out" and uncover flaws in the design. Factory testing is conducted by representatives of the design bureau, the factory, and the customer to determine whether the design meets the requirements of the TTZ.[337] Based on the results of these factory tests, the design drawings are further modified.[338] All documentation generated during this stage is assigned the letter "O."[339]

After the factory tests and prove-out of the initial pilot model are complete, the design bureau and its prototype shops begin to build the pilot lot. (If this is a large item, like an airplane, the pilot lot may be built in an "experimental plant," a specialized department of a large production plant that is still under control of the design bureau for the purpose of this prototype work.)[340] These pilot-lot series are the units that will be used in the state tests to prove out and qualify the design. As part of the building of these units, development of tooling and tooling design is started. The construction of these prototypes also involves the use of "model manufacturing processes," which by Western standards are experimental manufacturing techniques. As these model manufacturing processes are developed and proven out, they are incorporated in the item's "working technological documentation," which is developed for the system under the YeSTPP. (This documentation is also given the designation letter "O," like its counterpart in the YeSKD.) As the production technology and tooling are being developed, production engineering experience derived from building the pilot-lot prototype units is being fed back into the design documentation, raising it to a letter designation of "O1."[341] This model series "O1" is the one that, after initial factory testing, is submitted to formal state testing.

Prototype building and rigorous testing are standard features of the Soviet development system.[342] The Soviets believe in basing their production decision on the test results of real hardware rather than (as is often done in the West) on the theoretical promise of designers. Therefore the Soviets have a prototype testing phase built into their design cycle that requires design bureaus to submit their prototype for a set of rigorous state tests.[343]

337 Leebaert, p. 278.
338 GOST 2.103-68.
339 GOST 2.103-68.
340 Alexander, 1973, p. 428.
341 GOST 2.103-68.
342 Desmond, p. 17.
343 Amann, Cooper, and Davies, p. 324.To ensure that they can pass the state tests, design bureaus normally conduct an extensive series of factory-level tests at both the component and system level prior to submission of their pilot-lot units to formal state testing.

The state tests "are intended to see, as far as possible, how the system will perform in operational conditions."[344] These tests are conducted in accordance with a set of standards developed from the requirements laid out in the TTZ that is used as the basis for the system's development,[345] and with a number of standard requirements documents that apply to all systems developed for the military or industry. The test requirements are laid out in technical test specifications called the Test Program and Methodology (programma i metodika Ispytanit, MRTU)—a document that contains the technical characteristics that are subject to examination during testing of the item as well as the test procedure and technique for each individual weapon at the test range.[346] The MRTU requires testing not only of all the characteristics spelled out in the TTZ, but also of all the standard state test requirements, such as fungus resistance, effect of repeated mating of subassemblies, and cold-weather operation.[347]

These state tests are conducted under the auspices of a State Inspection Committee,[348] (mezjvedomstvennaya komisslya, MVK) set up to monitor system testing.[349] The committee is headed by an officer and includes representatives from the ministries involved,[350] their research institutes, the customer,[351] service experts, armament scientists, and designers. Such a committee "generally includes many people, sometimes several dozens or even hundreds, depending on the nature of the product."[352] The state tests, which are sometimes competitive,[353] "are normally conducted at the customer's testing ground." [354] If the unit passes the state test, the committee certifies the unit as ready for production, and the committee's recommendation, along with a technical specification for the system, is submitted to the customer for action on the formal production decision.[355] The technical specification (tekhnickeskie usloviya, TU) is developed by the inspection commission "on the basis of the MRTU testing. The TU is in force for the lifetime of the item and calls for state and acceptance testing of the trial model prototypes and serial production articles."[356]

If the units fail the MRTU test, the state inspection committee either flunks the design in its entirety or "asks the developer how much time is needed to correct the problem

344 Amann, Cooper, and Davies, p. 324.
345 Amann, Cooper, and Davies, p. 324.
346 Magnan, p. 92.
347 Magnan, p. 92.
348 Agursky, p. 9.
349 Magnan, p. 92.
350 Amann, Cooper, and Davies, p. 324.
351 Alexander, 1973, p. 429.
352 Agursky, p. 9.
353 Leebaert, p. 280.
354 Leebaert, p. 280.
355 Alexander, 1973, p. 429.
356 Magnan, p. 93.

and extends the testing schedule accordingly."[357] If a second modified experimental lot has to be built, it and its documentation are designated "O2" (a third lot will be designated "O3" and a fourth "O4") in accordance with the YeSKD requirements.[358]

The successful completion of state testing, with a favorable recommendation, is the end of what the West would call the development phase (though the Soviets regard the research-production process as much more continuous). Before this discussion of the development cycle concludes, four other aspects deserve mention.

The first of these is cost estimating. The Soviet cost-estimating system is more conservative than the U.S. system. U.S. cost estimating tends to develop and present the lowest cost estimate that can realistically be advocated (often called the salesman's cost estimate). This practice results in cost overruns. The Soviet design bureaus, by contrast, often pad and inflate their cost estimates above expected costs[359] to include unexpected future costs and to "skim off unallocated funds that the design bureau can use at its discretion."[360] The Soviets do not suffer the prevalent cost-overrun problems that the U.S. does, not because the Soviet designs are better, but because the Soviets start from a more realistic basis than the Americans. The Soviet practice of inflating estimates may reflect the fact that penalties for being wrong can be higher in the Soviet system than in the American one.

The second aspect of the Soviet development system that deserves mention is the length of the Soviet design cycle. Since the end of World War I, the time required to design military equipment (by all countries) has increased because of the size and complexity of modern military systems as well as their technical sophistication. Nevertheless, one hears much talk about the "ever increasing development time" of systems and what management practices ought to be changed to correct this inefficiency in current development methodology. The Soviet development cycle takes 6 to 12 years,[361] depending on the complexity and priority given the system, with the average being about 10 years for normal-priority systems:[362] marginally shorter than the time for development of U.S. systems. This disparity may, however, be a reflection of the Soviets' tendency to develop less complex single-mission systems[363] rather than an indication of superior Soviet management style.

Third is the fact that Soviet designers are much less inhibited than their Western counterparts about adopting foreign technology; the importing and adopting of foreign

357 Magnan, p. 92.
358 GOST 2.103-68.
359 Magnan, p. 26.
360 Magnan, p. 31.
361 Westwood, p. 146.
362 Westwood, p. 205.
363 U.S. Department of Defense, 1986, p. 112.

technology has become a major business in the Soviet Union. The issues of theft and conversion of Western technology are beyond the scope of this report; however, the Soviet method of copying a Western system in total is not. "When a (Soviet) . 'tomer service wants to duplicate exactly a foreign weapon in the shortest possible ti. ., two or more design bureaus may be ordered to duplicate or 'reverse engineer' a certain critical subsystem."[364]

The fourth aspect is the Soviet method of developing the industrial processing technology needed to manufacture a system. That technology is usually developed in an ad hoc way in the West and is often considered proprietary by the developing company. Even when the technology is not considered proprietary, it is seldom documented in a design package.[365] The Soviets, on the other hand, have a structured system for developing and documenting the industrial process technology required to build, manufacture, assemble, and process items necessary for their systems. The Unified System of Technological Documentation contains a formal system for developing and documenting industrial processing data. Under the YeSTD, a series of experimental and model manufacturing processes are developed, perfected, and documented. The development of the manufacturing and process technology needed to build a system is conducted in parallel with the development cycle of the system itself. Technological documentation, as the Soviets call it, goes through the same stages as the system and even uses the same lettering system for documenting its phases. Thus, when the weapon system or equipment is ready for production, the manufacturing methods and industrial process data needed to put the device into production are already finished, documented, and ready to be submitted to the series production plant. This documentation is a relatively complete manufacturing data package, including not only process and manufacturing data but work instructions and "norm controls" (work standards, in Western terminology).

The production decision follows the prototype-development phase in the Soviet cycle. Military prerequirement processes are designed to identify a recognized need for which a hardware requirement will be generated. In this regard, the Soviet and American systems are the same: each has decided early on, during the requirements phase, to buy some system to fulfill a need.[366] The manner in which each arrives at a decision to buy a given system, however, is quite different. In the U.S., that decision is often determined by the time advanced development is over: we have built only one system. The Soviet military development processes often generate more than one candidate to meet a production requirement.[367] The Soviet tendency to develop competitive prototypes, coupled with the fact that under the Soviet evolutionary-development methodology customers can often choose to wait a year or two until a new series of prototypes comes along, gives the Soviet

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364 Magnan, p. 52.

365 This is true in the U.S. because of the way that DOD drawing standards are set up and because of the negative view courts have taken of erroneous processing data on the drawings.

366 Leebaert, p. 280.

367 Amann, Cooper, and Davies, p. 317.

decision makers a more flexible environment in which to make a production decision than their American counterparts. In this choice-rich environment, two situations occur. First, in the Soviet system, "the series production decision does not follow automatically from successful state trials."[368] In all probability, a significant portion of items that pass state tests never get put into series production. Second, "development can be a 'business' unto itself, rather than just something done for the short-term objective of getting a follow-on production program."[369] Under the Soviet system, the prototype is the design bureaus' salable commodity."

The Soviet service customer makes its production decision by selecting the system that it thinks will best serve its need from among the available choices. This decision, as in the U.S., is made or at least reviewed at a reasonably high bureaucratic level. In the U.S., however, the decision to produce a weapon is often made by the same people who made the decision to develop the weapon, whereas "In the Soviet Union, the decision to develop a weapon is often conceptually and organizationally distinct from the decision to produce and deploy it."[370] This dichotomy has distinct advantages for the Soviet decision makers, aside from the obvious one of not being committed to a weapon system too early. The major advantage is a greater ability to judge the cost and risk of a program if put into production. Under the Soviet system "the use of prototype construction and operational testing provides information on the costs and performance of the new weapon that is critical for the production decision."[371] The prototype procedure also provides a way of eliminating the risk of incorporating new technologies into the system,[372] which gives the Soviet decision makers greater certainty than their American counterparts in making the production decision.[373] Once the prototype design is approved and the production decision made, funds are provided for the deployment of the system into production.[374]

This production decision and its associated funding mark the transition to the trial-production (ustanovochnyye serii) phase.[375] Documentation for this phase is designated by the letter "A."[376] At this point the system moves from under the control of the state standard that guides design and into control of the two series of state standards (YeSTpp and SRPP) that govern the transition of a system into production. The overall management and direction of the transition to production is controlled by the SRPP lead document, GOST 15.001-73, which outlines the steps to be taken by management to make the transition successful. Most of the work to be done is outlined in the standards of the

368 Leebaert, p. 280.
369 Gansler, p. 251.
370 Murray and Viotti, p. 176.
371 Murray and Viotti, p. 176.
372 Murray and Viotti, p. 176.
373 Alexander, 1973, p. 432.
374 Desmond, p. 22.
375 GOST 2.103-68.
376 GOST 2.103-68.

YeSTPP, which define the technical requirement steps. These steps are organized by the SRPP hand-over standard into a coherent and orderly process. The YeSTPP provides the following rules for a design undergoing transition into production:

1. Rules for providing for the producibility of an assembly (GOST 14.203-73)
2. Rules for providing for the producibility of parts design (GOST 14.204-73)
3. Rules for the development and application of standard manufacturing processes (GOST 14.310-73)
4. Rules for the organization and development of manufacturing equipment sets for production lines (GOST 14.310-73)
5. Rules for development and setup of working manufacturing processes (GOST 14.311-75)
6. Requirements for economic tradeoff studies of manufacturing methodologies (GOST 14.005-75)
7. Rules for working up the design of an article for producibility (in Western terms, producibility requirements) (GOST 14.201-73)

In addition to these specialized technical requirements, the YeSTPP system contains six sets of general guides to the management, engineering tasking, and documentation associated with the transition to production.

The rules outlined in the YeSTPP are more than a standard for review at the point of the transition of an item to production; they are an integral part of the design process. This approach differs from that of the West, where a producibility review is held at the end of the design, after the design has been finalized and at a point when few changes can be made. The Soviet producibility rules are meant to influence the design at an earlier stage while the design is still fluid and can be affected to great advantage by incorporating the manufacturing and tooling requirements. That is why the contents of the YeSTPP are called rules rather than review requirements, though mandatory reviews of a number of aspects of the design are held as part of the transition process. These reviews are meant to be more of a check of the designers' quality of work than an independent means of installing producibility in the design. Furthermore, since Soviet designers know that their product is going to be heavily reviewed for producibility, they strive harder to increase the producibility of their designs (more so than their Western counterparts, whose work is not so heavily reviewed in this area).

The YeSTPP not only reaches down and affects the producibility of the design, but also provides an organized, structured framework for the movement of a design into production and a methodology to manage this transition. Under the influence of these two sets of standards, the "trial-production phase can be divided into two sub-phases: one including documentation and production preparation, and the other production prove out and field testing of the production design."[377]

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377 GOST 2.103-68.

Upon release to production, a system enters a documentation-upgrade and production-preparation phase that consists of several parallel activities. One of these is the drafting of the technical specification or technical conditions (TU), "which lays down the requirements for series production. It sets out the purpose of the product, its sphere of application, the basic tactical-technical data, the parameters that govern its suitability for delivery to the customer, the methods of quality control, the guarantees of the manufacturing enterprise, the packing and transport requirements, and so on."[378] This document also forms the basis of the contract between the Ministry of Defense and the production ministry for series production. The contract is executed at this time.[379]

Another activity during this phase is the selection of a series production plant to produce the system. Series production plants that manufacture weapon systems are not permanently linked to specific design bureaus.[380] The manufacturing facilities, like the design bureaus themselves, are owned by the Defense Production Ministry involved in the development. One of the first activities that the ministry must perform after the service customer and the Ministry of Defense have made their production decision is to select a series production plant that will build the item, a selection that is made on the basis of technical capability and work load. Once the production plant is chosen, its director and engineering staff become intermittently involved in the weapons design and transfer processes.

Meanwhile, update and conversion of the drawings are under way. Results from the state trials often reveal minor weaknesses that must be corrected before manufacturing begins, and so the design engineering team starts to rework the drawings.[381] At the same time, a team of production engineers from the selected series production plant joins the design team, and detailed production design work begins on the system. This joint team "converts the preliminary drawings used for the construction of the prototype into production drawings suitable for plant use. . . . [in this process] . . . the series plant engineers advise the designers on plant capabilities and costs of alternative (manufacturing) technologies"[382] and advise on producibility.

While this process is ongoing, the design and its drawings are put through another systematic and rigorous standardization review. As noted earlier, standardization amounts to a national policy.[383] A standardization section in the design bureau has worked on and reviewed the drawing; however, as the design moves through the transition to production, the standardization section of the series production plant reviews and reworks the design

378 Amann, Cooper, and Davies, p. 325.
379 Amann, Cooper, and Davies, p. 317.
380 Alexander, 1973, p. 428.
381 Alexander, 1973, p. 430.
382 Alexander, 1973, p. 429.
383 Desmond, p. 20.

drawing in an attempt to achieve the highest possible degree of compatibility with standard industrial practice.

The decision to have and use common parts and components weighs much more heavily on the manufacturing plant than on the design bureau. Chronic supply problems in Soviet industry make the supply of specialized parts extremely unreliable, a fact that can affect the efficiency and quota accomplishment of the enterprise. To avoid such problems, the use of standard off-the-shelf items rather than newly designed items is encouraged by the Soviet production managers and their industrial standards sections.[384] The Soviets believe that whatever is lost in system optimization by this process is gained in system reliability and producibility.[385]

With the selection of the series production plant, the influence of the plant's management becomes a major factor in the production-engineering design of the item. Soviet plant managers constitute one of the most powerful and influential segments of Soviet society, and their opinion of how the system should be run has a strong influence even on the design of military equipment. Soviet plants and their managers' performance are essentially judged by their ability to fulfill a monthly plan,[386] so Soviet industrial managers try to have as undemanding and uncomplicated a plan as possible. At a higher industrial level (and in the Soviet consumer economy), this preference by the managers results in endless negotiations between industrial managers and GOSPLAN, the Soviet state planning agency that sets plant quotas. At a weapons-design level, this preference manifests itself as a bias in favor of simplicity and ease of production in weapons and systems. Soviet industrial managers and administrators object to "unreasonable" quality demands and to excessively "pretty" weapons.[387] Thus, the design team is under great pressure during the production-engineering (trial-production) phase to make the weapon as simple and easy to produce as possible, another example of the legacy of the Soviet World War II experience.[388]

As the update and conversion of the drawings proceed, the series production plant starts preparation and planning for production of the item. The design is reviewed to determine its production requirements, both from technological and tooling points of view. The YeSTPP system contains a formal procedure for development of "working technological documentation" for the industrial process and of manufacturing technology needed to develop the technology to build the weapon. This procedure includes the "use of model manufacturing processes" to develop the technology and skills necessary to manufacture the item. The Soviets even have a separate term to identify this class of work:

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384 Alexander, 1973, p. 431.
385 Alexander, 1973, p. 430.
386 Valenta and Potter, p. 101.
387 Valenta and Potter, p. 101.
388 Gansler, pp. 281-282.

"Experimental Technological Work" (OTR), which is defined as design and assembly of the needed production capability.[389]

A tooling requirements analysis is performed to determine which pieces of the system can be built on standard tooling and which pieces require specialized tooling.[390] Performing the tooling analysis this early in the production cycle has great advantages in increasing the producibility of the system by permitting substantial interplay between the tooling designer and design personnel who are developing the production-engineering drawings. This procedure is quite different from the U.S. practice, on military systems, of giving the tooling engineers a set of finished drawings with instructions to build the tooling, gauges, and assembly fixtures for building the end item to specified tolerances. The Soviet system permits the tooling and production engineers to have an impact on the tolerances and design features of the parts, which aids the manufacturing enterprise in simplifying production and reducing costs because it permits the tooling designers to question and often reduce or eliminate design features that have tight tolerances or that are difficult to manufacture and inspect. This interplay often permits significant reduction in the complexity and cost of tooling and gauging with no significant adverse effect on the design, whereas in the American system such features are simply accepted as "a given" in the design, and their costs are passed on to the buyer (the Department of Defense).

Once the design drawings are raised to the level required for production (letter "A" status), the changes are incorporated into a single prototype model. This prototype and the completed drawings are then formally submitted to the series production plant to begin the trial-production phase,[391] and a group of engineers from the design bureau is assigned to the plant to help during the period of initial production.[392] This assignment helps to develop a good working relationship between the plant and the design bureau.[393] It is customary for junior design engineers to spend 2 or 3 years on such an assignment early in their careers.[394]

The production plant then begins trial series production. These trial units, which are built with hand tooling and "model manufacturing processes," are submitted for field tests and troop trials.[395] Field testing can be quite extensive in the case of a major weapon system like a tank and can involve several hundred units. Failing these field tests can kill a major system even though it is already in initial production; however, this result is unusual. The more normal procedure is for the test to generate modifications and design changes that are incorporated into the design drawings before the system is released to unlimited series

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389 Westwood, p. 203.
390 Alexander, 1973, p. 431.
391 Alexander, 1973, p. 428.
392 Desmond, p. 22.
393 Amann, Cooper, and Davies, p. 318.
394 Westwood, p. 315.
395 Murray and Viotti, pp. 176-177.

production.[396] At the point of incorporation, the drawings become full production drawings under the Unified System for Design Documentation and are designated by the letter "B."[397]

Although the Soviets have a formal system to transition a system into production (which the West does not have), that does not imply that there are no impediments to such transition in the Soviet system. One of the reasons the Soviets have such a formal system is that other parts of their centralized management system oppose the transition of a new item into production. In fact, "most students of the Soviet economy agree that, although the central authorities would like to see a greater degree of product innovation, the way in which the economy is organized makes the transition between research and production stages of the research-production cycle difficult, and creates disincentives for enterprise to shift to new lines of production."[398]

The performance of Soviet enterprise tends to be measured by gross output. The disruption to production caused by the introduction of a new item can reduce, at least in the short run, the total volume of output, and this reduction in volume may in turn reduce the factory's apparent performance and thus its bonuses.[399] (Why the Soviets have not attacked this problem with a large bonus for successful completion of the transition of an item to production is a question for which the author has no answer.) For the same reason, plants will resist terminating long production runs to retool for a new product.[400] Compounding the problem is the fact that, under the Soviet economic incentive system, a program generally does not become profitable to the plant until the third or fourth year.[401]

Countering the reluctance on the part of the plant to accept new systems is the fact that the design bureaus get a substantial portion of their total bonuses when a system completes the transition to production. This encourages the bureaus to develop systems oriented toward ease of production [402] and to make the production transition as easy as possible.

Once the changes that were identified in the field tests have been incorporated into the design, the system is ready for its release to series production (unlimited mass production). The release decision, made at a high political level, is based both on the perceived need for the system and on policy considerations. Once the decision is made, an order is issued by the procuring armed service to the plant to commence production of the system at some given rate.

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396 Cochran, Arkin, Norris, and Sands, p. 95.
397 GOST 2.103-68.
398 Amann, Cooper, and Davies, p. 341.
399 Amann, Cooper, and Davies, p. 342.
400 Amann, Cooper, and Davies, p. 343.
401 Amann, Cooper, and Davies, p. 343.
402 Gansler, p. 251.

There is an important difference here between U.S. and Soviet acquisition systems. In the U.S., a contract is let for one year's production to a company, but that contract for production will be relet by competitive means the next year and may go to another company. The Soviets authorize a producer to produce at a given rate for a number of years. This difference in approach affects the design life of tooling and fixturing, its degree of specialization, and the dedication and layout of production facilities. These issues have a profound effect on the productivity and efficiency of the production line and have a corresponding effect on the cost of the system in production.

The Soviet production world is different than its Western counterpart. These differences influence how a system is built and what it looks like at a detailed mechanical-assembly level. At that level the system often appears strange to one who does not understand the dynamics of Soviet production. One of the basic factors driving the difference in approach is that the Soviet Union is the only modern society that runs a physical economy in peacetime.[403] In this type of economic system, expenditures are measured in terms of real materials and human labor, not in terms of money.[404] In fact, the ruble is not really money as a Westerner understands it.[405] "The pricing system does not reflect scarcities;"[406] it is not used to allocate resources, but instead is used as a "social accounting convenience" (a Soviet term of "economic art"). Expenditures of real resources are controlled by a central industrial allocation system, and "a simple money budget is not adequate to guarantee the availability of resources that have not been planned and allocated in advance."[407] Therein lies one of the Soviet production organizations' major problems; "in the centrally planned Soviet economy, supplies are allocated far in advance of actual need. Optimistic planning targets create a general shortage of materials, where a buyer may be required to accept an inferior product or go without."[408]

To shield the defense industry from the shortcomings of the rest of the economy, the Soviets have established a priority system.[409] When a Soviet defense plant manager gets a contract, he also receives a set of allocation certificates (naryady-zajazy)[410] from his program authority. These certificates, in theory, give him the material required to do the assigned job. This system suffers from the problem of all allocation systems, namely that the material must actually exist to be allocated. In the Soviet system it often is not. This problem is somewhat alleviated by giving defense plants the power to commandeer what they need from civilian industry, which is an important advantage in an economy where

403 Satellite states are also incorporated to some degree into the Soviet physical economic system.
404 Westwood, p. 78.
405 Westwood, p. 80.
406 Westwood, p. 78.
407 Alexander, 1978, p. 16.
408 Murray and Viotti, p. 174.
409 Amann, Cooper, and Davies, p. 313.
410 Amann, Cooper, and Davies, p. 312.

supply problems are chronic.[411] Using the powei, however, creates adverse political pressure on the industrial enterprise; the pressure comes from the civilian power structure of the local district involved whose economy suffers.

The Soviet economy suffers from a shortage of supplies that affects even military products. To avoid this, military production ministries and individual production factories try to keep as much of the manufacturing process as possible within their organizations.[412] "The Ministry of Aviation industry includes metallurgical plants that roll aluminum and magnesium alloys, stamping and extruding facilities, and plants that manufacture plastic and rubber goods"[413] for use in the aircraft industry. The Aviation Ministry produces 90 to 95% of all the thousands of components that are used in aircraft.[414] and is typical of Soviet production ministries, whether civilian or military. In the same way, the chronic unreliability of supplies influences individual Soviet plants to try to be completely self-contained in their manufacturing operations, or at least to rely only on known outside suppliers with a proven track record.

Many people contend that Soviet weapons are made in unsophisticated (by Western standards) plants and facilities, made to minimum standards and tolerances, and use manufacturing processes designed for unskilled or semiskilled laborers. While these contentions may reflect the reality of the Soviet production environment, they also constitute a culturally biased analysis that misunderstands the reason for the appearances. The Soviet Union is still undergoing the transition from an agricultural society to an industrial one, and a large number of ex-peasants, who do not possess high-grade industrial skills and can be employed only in unskilled or semiskilled jobs, have migrated to the cities within the last generation . This large low-skilled labor pool allows Soviet industrial engineers who are designing manufacturing facilities to make the economic trade-off between the use of manpower and the use of assembly machinery at a different point than would an American engineer.

Labor availability affects how a production engineer inputs into the design. If the engineer is going to have someone tighten a bolt by hand, he makes one recommendation for the design; if he is going to have the bolt handled by an automatic insertion machine, he makes a different recommendation. That the Soviet industrial engineer tends to make the trade-off more often toward the use of manpower than his American counterpart is true; this approach, perceived as unsophisticated by Westerners, is a reasonable industrial economic decision to use a lot of lowly compensated people and inexpensive machinery. Similarly, when it is observed that Soviet weapon systems are designed for assembly by the highly labor intensive methods and

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411 Holloway, p. 119.
412 Alexander, 1973, p. 427.
413 Alexander, 1973, p. 427.
414 Dunlavy. p. 3.

> . . . are not designed for automatic production, the initial reaction of American engineers is that they are not very "producible." However, it must be recognized that this assessment is based on their suitability for production in the United States. Within the Soviets' industrial environment, Soviet manufacturing specifications are very functional and practical, probably more so than American ones.[415]

This labor-intensive production method should not, as it often is, be interpreted as reflecting an absolute lack of high-grade production skills. The Soviets employ sophisticated production technology when they feel that it is in their interest to do so. Nor should it be interpreted, as it often is, as a sign of an incompetent work force. In World War II, the German Ministry of Armament conducted an elaborate series of studies to determine who among the conquered and subject peoples used as conscripted labor in its war plants made the best and most efficient workers. This study showed that Russian peasant women were the most efficient and productive working group in the whole of conquered Europe,.[416] doing the repetitive mind-numbing industrial assembly jobs better than any other nationality under Nazi control. This aptitude for the job may also have affected the Soviet decision to stay with the labor-intensive method. To say that this labor-intensive method of manufacture indicates a primitive and unsophisticated manufacturing process is also a misreading of American industrial history. If one looks at the period of migration of agricultural workers into the industrial labor force in the United States, which occurred from 1880 to 1970 (being essentially over for all groups except Southern blacks by the close of World War II), one finds that as long as an adequate supply of competent hands-on labor was available, plants were generally run on a labor-intensive basis. Only with the demise of an available, competent labor force did the large-scale, specialized, and automated manufacturing and assembly equipment equipment, which is today viewed as "sophistication," come into general use.

Nor can it truly be claimed that the Soviet labor force is incompetent; the so-called unskilled labor force consists of adequately skilled agricultural workers who are steady and hardworking and will often continue to work diligently at their assigned tasks in industrial working conditions that would appall a union steward in the West. This is not to say that the Soviets do not have an industrial labor discipline problem in their factories, nor that the level of technical skills in the population does not impose a major constraint on the development and production of armaments.[417] The Soviets' industrial labor discipline problem has, in fact, reached sufficient size to warrant the attention of the highest level of the Soviet government. These problems, however, have little bearing on the production methodology used by Soviet enterprise on the shop floor to make and assemble military hardware.

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415 Kehoe and Brower, p. 705.

416 Alan S. Milward, *War, Economy and Society 1939-1945* (University of California Press 1979), p. 228, and Edward L. Homze, *Foreign Labor in Nazi Germany* (Princeton: Princeton University Press, 1967), pp. 240-265.

417 Leebaert, p. 281.

Military production factories are reasonably insulated from labor disruption because they generally have a better caliber of work force than nonmilitary factories. The high-caliber worker is enticed by better pay (generally 10 to 20%), better working conditions, and fringe benefits such as housing. Also, better workers are deliberately shunted into defense plants by the authorities.

The population's level of technical skill affects the ability of the Soviets' military enterprise to carry out sophisticated manufacturing operations, but, it does so by affecting the kind and amount of technologically advanced machinery and materials that can be used, rather than by directly influencing the production engineer's choice of technologies available on the shop floor. Instead of using special-purpose machine tools, he builds parts on banks of general-purpose machine tools because he has a lot of low-paid machinists, and he sews leather insulators on to cable assemblies by hand (rather than use lacing machines) because he has a lot of low-paid seamstresses. In the Soviet engineer's industrial economy, it is less expensive for him to do it that way. Despite Western preconceptions about the crudeness and lack of sophistication of Soviet equipment, close inspection shows that the Soviets have often used their labor in very clever ways to overcome their production problems. The American engineer cannot do because he does not have the large quantity of skilled "craft and touch" labor.

In addition to the abundance of low-paid skilled laborers, Soviet production plants use general-purpose machine tools, as opposed to the West's more specialized and automated production-plant equipment, because of a problem in the general Soviet economy. Soviet machine tools are made according to a plan that runs in 5-year increments and is set up several years in advance. Because it is difficult to project specialized tooling requirements that far in advance, the Soviet planners opt to build more flexible general-purpose machine tools.[418] The Soviet planners also like large plants[419] and, as a result, the Soviet machine-tool industry consists of 90 large plants[420] that produce large numbers of standard items to plan. The system is very inflexible. The average lead time for getting special-order production tooling out of the system is 3.1 years.[421] If one wants something really special and unique that is not in the present plan, and it must be put in the next plan, the item will take 8 years to materialize.[422]

Herein lies one of the major shortfalls of the tooling section of the Soviet economy. No demand sector exists to supply specialized production machine tools to meet the needs of a given enterprise in setting up its production line. The plant's industrial engineering

418 Amann, Cooper, and Davies, p. 144.

419 The desire for bigness is characteristic of the Soviet planning system. The Soviets like to build "big" projects, preferably the largest in the world.

420 Amann and Cooper, 1986, p. 96.

421 Amann and Cooper, 1986, p. 85.

422 Amann, Cooper, and Davies, p. 144.

staff has to piece its tooling layout together using the general-purpose tooling available. The Soviets do not even have a secondhand machine tool market, as the United States does.[423] Enterprises prefer to keep the older machine tools that have been allocated to them in reserve rather than declare them surplus and submit them to their ministry for reallocation. Thus, industrial engineers setting up production lines in Soviet factories tend to use the machinery that they have on hand to build the product assigned to them rather than try to put together a more optimum production tooling set by acquiring new equipment.[424] In this environment, production problems are solved by more clever use of existing equipment[425] rather than by acquiring new, specialized production machinery.

Two other aspects of the tooling environment affect the floor-level operation of the Soviet production plant. First is the accuracy characteristics of Soviet machine tools. The Soviet state standards for machine tools generally specify a lower level of accuracy to be built into their machines than are built into their Western counterparts,[426] which results in a lower tolerance capability on the factory floor. Secondly, there is no specialized job-tooling industry in the Soviet Union. In the West, when one sets up a new production line, one buys large amounts of specialized production job tooling to equip the line. These jigs, work-loading fixtures, holding plates, dies, assembly fixtures, molds, drilling fixtures, arbor presses, gauges, specialized cutting tools, etc., lack the glamour of the machine-tool business, but they are nonetheless vital to setting up an efficient production line.

In the West, such tooling is procured from hundreds of small specialty firms that have unique capabilities in narrow specialized areas, or the tooling is built to order by free-lance tool and die shops, often one to three tool makers in size, that specialize in making a given type of die or assembly fixture. The Soviet Union has no equivalent to these small, specialized, production-tooling job shops, so the factory itself has to build all its own job tooling.[427] The lack of outside tooling resources necessitates that a Soviet plant run a large tool-room operation that occupies many high-quality tool-making personnel and much specialized precision tool-making equipment. In many ways, the Soviet tool-room operation resembles those of large American factories in the first half of this century and suffers from the same difficulties: lack of personnel with unique specialized skills and chronic under-use of equipment.

If an American production engineer were to walk through a Soviet military factory, another facet of tooling use policy would become apparent after some examination of the operation. Because of the Soviet Union's chronic supply problem, factories try to run closed cycle, with most components for the end product being made by the factory

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423 Amann, Cooper, and Davies, p. 143.
424 Some extra-legal trading of machine tool appears to go on between factory managers.
425 Westwood, p. 305.
426 Amann and Cooper, 1986, p. 96.
427 *The Soviet Union* (Alexandria, Virginia: Time-Life Books, 1985), p. 150.

itself.[428] The Soviet production-line tooling is therefore set up on a line-of-necessity basis, as opposed to the line-of-balance basis common in the West. Under a line-of-necessity basis, a machine tool needed to perform an operation is put in the line and dedicated to that operation even if the tool is required to be run only a small part of the time (5 to 20%) to meet its output goals.

An American industrial manager, confronted with this set of circumstances, chooses one of three alternatives: buy the part or operation from an outside source, out-job the surplus machine time (get a job from outside the plant to use the machine to supply parts for someone else), or find a down-time product to build and sell as a sideline. In the Soviet Union none of these solutions is available. Soviet enterprise tries not to rely on outside supplies, which is why the machine is underused in the first place. Soviet factory managers are also loath to take on small outside piece-part jobs that might affect their ability to meet their quotas and at the same time might get them in "hot water" for affecting someone else's ability to meet his. As for small down-time products to sell, that is illegal in the Soviet Union. The Soviet Union works by plan: if it is in the plan, there is a quota for it; if it is not in the plan, using state equipment to build it is illegal. So, with the exception of some extracurricular "nalevo" (black-market) work[429] by the employees themselves, there aren't any down-time jobs, and the equipment stays idle. The Soviets are left with a great deal of underused equipment, which results in negative comments by Westerners on the poor equipment-use rate.[430]

The working production technology of a Soviet factory also differs from that of a Western facility. In certain areas, the Soviets have better deployed production technology than the West. For example, the Soviets lead the world in welding technology, so welding assumes a higher position among the fabrication techniques.[431] Soviet expertise in this area includes the welding of many difficult assemblies and materials that would not or could not be done in the West. Another example of Soviet superiority in deployed production technology is the extensive use of very large presses to fabricate components in sizes and with efficiencies that are unsurpassed[432] and not even approached in the West. This capability exists because the Soviets have continued to develop the large-press production technology pioneered by the Germans in World War II, while the West has not. The Soviets have built the largest production presses in the world: 75,000-ton forging presses and 20,000-ton extrusion presses are regularly used to turn out production parts in a manner unknown to the West.[433]

428 Amann, Cooper, and Davies, p. 141.
429 Hedrick Smith, *The Russians,* (New York: Ballantine Books, 1976), pp. 106-134.
430 Agursky, p. 12.
431 U.S. Department of Defense, 1981, p. 77.
432 U.S. Department of Defense, 1981, p. 77.
433 Unless they had studied the old German data, most Western production people would not know how to use such production tools if they had access to them.

Soviet use of materials also differs from that of the West. Soviet designers and production engineers use the materials that are available to them or those specified in publications such as the "All Union Institute of Aviation Materials; Handbook of Materials."[434] The Western observation that Soviet military equipment sometimes makes odd use of high-technology materials[435] is a culturally biased comment. The Soviet designer and production engineer have selected a suitable material that is available in their supply system and that is not available in the West for that application because of cost or scarcity. The leading example, of course, is titanium. Because the Soviets have put great effort into titanium-production facilities, the material is abundant enough that submarine hulls are built of it. Titanium is still a relatively high-priced aerospace rarity in the West.

The crude finish in noncritical areas, often noted by Western observers,[436] is "generally the result of a very practical trade-off between ensuring adequate performance and minimizing production costs."[437] In this regard, the Soviets must be judged to be more flexible than the United States,[438] where aerospace designers generally machine-finish all surfaces, regardless of whether there is any functional requirement to do so. The Soviets pay "little attention to unnecessary cosmetics and finishes."[439] They do finish critical and working surfaces where they are needed, but their shop practice is to leave everything else in process state (no secondary operation to improve appearances). While the result may appear crude, it greatly eases production and reduces the overall cost of a component significantly.[440] It is the author's opinion that this is one area where Soviet production practice is significantly superior to the West's.

Production in the Soviet Union is driven by cultural and economic forces just as it is in the West; the fundamental difference is that the two worlds have different realities, and the Soviet production processes are optimized to their economic reality, not to ours. What we see when we look at a piece of Soviet equipment is not incompetence and lack of skill: when we interpret it as such we are suffering from industrial culture shock. Soviet production engineers optimize their production on "the basis of available technology and production facilities,"[441] just as a Western production engineer does.

Another factor affecting the Soviet production environment is a side effect of the Soviet work-incentive system. The Soviet production factory works on the basis of monthly plans. To get the monthly production bonus, the factory must fulfill the plan

434 Alexander, 1973, p. 428.
435 Luttwak, 1984, p. 107.
436 Desmond, p. 17.
437 Kehoe and Brower, p. 709.
438 Kehoe and Brower, p. 709.
439 Dunlavy, pp. 5-6.
440 Western studies show that the Soviet dimensional and finishing practice probably results in a 10 to 15% cost saving on components.
441 Leebaert, p. 281.

100%. A single unit shortfall deprives all employees and management of their monthly bonuses.[442] Since the bonus is equivalent to 20 to 30% of the monthly pay,[443] there is great pressure to meet the monthly plan.

This pressure has led to the practice the Soviets call "storming" to meet the monthly production goal and fulfill the monthly plan. In practically every kind of industrial plant, the pace of the month's work tends to move forward in three distinct 10-day periods described by one Soviet worker as spyachka, "hibernation," gorychka, "hot time," and likhoradka, "feverish frenzy" or "storming."

During the first 10 days of the month, spyachka, key supplies are usually missing, many workers are absent, and little gets done. During gortachka, 10 days during the middle of the month, parts start dribbling in from suppliers and the pace increases. In the final 10 days of the month, Likhoradka, the rest of the supplies arrive, and the manager throws in hidden reserves of workers and puts everyone on overtime.

During the storming period, managers put their office staffs on the production line and often work their crews two shifts, 7 days a week. A typical factory may turn out 80% of its monthly quota in those 10 days of storming. The result is fatigue and exhaustion, which leads to the disintegration of the quality of the output.[444] The effects of storming on quality (at least in the civilian sector of the economy) are a disaster. Goods are tagged with the date of production, and consumers try to shun anything made after the 20th of the month.[445]

Storming affects the entire Soviet economy to such an extent that the Soviets have developed a term to describe its effect: shtrumousehchina.[446] The bad effects of storming are known to the Soviet leadership, and several schemes to stop it have been proposed over the last 20 years. Some of these have been debated all the way up to the Politburo itself, with little apparent effect.

The plan and fulfillment systems that led to storming also significantly affect the Soviet production environment in another way. Soviet planners traditionally raise a factory's production goal every year (or at least they try to.), based on the factory's successful accomplishment the preceding year. This attempt results in a complicated negotiating game between the factory manager and the central planning authority.[447] Some people (like this author) have long questioned whether the continuous increase in

442 Amann and Cooper, 1986, p. 46.
443 Smith, p. 310.
444 For an extensive account of storming and its effects, see Smith, pp. 285-289.
445 Time-Life Books, p. 150.
446 Smith, p. 286.
447 Robert G. Kaiser, *Russia: The People and the Power* (New York: Pocket Books, 1976), pp. 351-353.

production quotas, which is constantly strived for by the planning bureaucracy, without any increase in capital (new machinery) and labor, has not driven the plant's production quotas beyond the optimization point for their physical facilities. This trend is similar to constantly raising the norms on piecework in Western factories. The upward slide of the norms in a piecework environment will ultimately reach a point where the fatigue limit, on both people and machinery, will cause the overall performance of work operations to fall below its optimum point. This decline appears first in quality and then expands to a slow decline in overall quantity as productivity declines. Recently, as part of General Secretary Gorbachev's perestroika campaign, factory managers were allowed to reset their own production quotas. To the horror of the central planning bureaucracy, the average factory manager cut output by 30% on the grounds that the central planners had set the goals "unrealistically high." This would indicate that the Soviets have been running the factories beyond their optimum point.

While the Soviet military production economy is insulated to some extent from the worst effects of storming, it is not immune. Storming and quota-driven shortcuts go on in military plants just as in civilian ones. The reason "that the quality of Soviet military material compares favorably with that of most products of the civilian economy"[448] is not a difference in technological levels between the two sections of the economy, which are essentially the same, but rather a difference in the quality control system used on the military-production lines.

Military-production factories are assigned a military representative (voennye predstaviteli), of the technical administration (armed service) that buys the hardware.[449] This voennyedy, who is responsible for ensuring "that the quality of production conforms to specification,"[450] may be a group of military engineers, technicians, and office personnel, or it may be a single officer.[451]In large plants, the commander of this military team is a field-grade military officer equal in experience and status to the plant manager.[452] These officers generally have engineering qualifications and are assigned 4- to 5-year tours of duty at a given factory.[453] They are responsible to and paid by the Ministry of Defense and, unlike the departments of technical control (otdely tekhnicheskogo kontrolya) in civilian production, "they have no financial interest in the factory's plan fulfillment, and hence no incentive to accept defective goods."[454]

Military representatives "exercise strict quality control throughout the production process, and conduct tests to ensure that the equipment being delivered to the Armed

448 Amann and Cooper, 1986, p. 44.
449 Amann, Cooper, and Davies, p. 325.
450 Amann, Cooper, and Davies, p. 330..
451 Amann, Cooper, and Davies, p. 325.
452 Amann, Cooper, and Davies, p. 325.
453 Donnelly, Christopher, "Jane's Defense Weekly," 19 November 1988.
454 Amann, Cooper, and Davies, p. 325.

Forces adheres to the standards laid down in the TU."[455] The military representatives have considerable power and "are reported to be quite willing to exercise their power to refuse goods which do not meet specification."[456] This willingness is bolstered by two facts. First is that "The Ministry of Defense does not have to pay for production which does not pass the quality-control tests applied by the military representatives."[457] Second, the military representative is "criminally liable for acceptance of products" that are defective,[458] and "if an item is found to have flaws, responsibility can be placed directly on the voyenpred who approved it."[459]

Soviet production runs of major equipment are often very long. Some analysts have pointed out that the average life of a fielded Soviet military system or technology is 15 years, and that during this period it remains largely unchanged.[460] This longevity is the result of two forces: the planning cycle and the change-control process.

The Soviet planning cycle works in 5-year increments. The procedure is to tool up a factory and let it run until the tooling starts to wear out, which takes 12 to 17 years. The replacement decision is usually at the end of the third 5-year plan after the one during which the factory started production. In some major systems such as tank production, the Soviets simply have three large plants and retool one during each 5-year plan.[461] Under this system, once a plant is retooled, it continues in uninterrupted production on the same item until its time in the planning sequence rolls around again.

Toward the end of the life cycle, these plants turn out obsolete, but still serviceable, equipment that is used primarily for export to the Soviet Union's clients and allies, and maintain a supply and spare-parts base for Soviet units still equipped with the product. A plant at the lower end of its life cycle often has an attached facility to rebuild worn-out equipment.

Soviet production culture militates against a high rate of minor production changes, and the Soviets' change-control process is reinforced by "the long tenure and wartime experience of the military industrial managers [which are] likely to have induced a strong sense of the value of continuity in design and production . . . the system is influenced even today by the intense emphasis on production during the war, and Stalin's insistence that change be held to a minimum to avoid disrupting production lines . . . ."[462]

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455 Amann, Cooper, and Davies, p. 325.
456 Amann, Cooper, and Davies, p. 325.
457 Amann, Cooper, and Davies, p. 313.
458 Westwood, p. 176.
459 Scott, p. 55.
460 Westwood, p. 436.
461 See David Holloway's excellent study of the Soviet medium tank industry in Amann, Cooper, and Davies, pp. 416-446.
462 Murray and Viotti, p. 168.

Individual interests also are a factor in resisting efforts to change designs. If the designer wishes to change the equipment in some manner, he is confronted by the factory manager. Factory managers are judged by their ability to fulfill a monthly plan and therefore want a plan that is as uncomplicated as possible. Because any change in production is inevitably associated with some type of temporary production problem that can threaten plan fulfillment, the defense industry administrators have every reason to prefer weapons that are not being continually changed, are opposed to endless model improvements, and resist vigorously attempts to modify the task assigned to them.[463] If the production-plant manager wants to make a change, he is confronted by the problem that he doesn't control the design's documentation. "In military industry the sundry documentation that the development bureaucrat hands down to the producer assumes the force of law. The plant can make no unilateral changes in the documentation, and the development bureau generally remains against proposed changes. This has its shortcomings, as designer's mistakes often exact their toll from production and greatly raise the cost of products."[464] Ultimate control over the design is retained in the hands of the chief designer of the design bureau that originates the design.[465] During the period that the design is under production, the designer, who has a large amount of authority over the plant manager in questions concerning manufacture,[466] resists tampering with the design for manufacturing reasons.

The effects, then, of the planning cycle and the change-control process are that "Soviet weapon systems (tend) to have long production runs, and changes during construction are limited in number."[467] This tendency emphasizes the importance of the plant's production engineering input in the early design-transition phase.

Change control versus design authority becomes an even more severe problem when two or more plants are manufacturing an item. The Soviets use a leader-follower system in setting up a second plant up and bringing it on line. In this system, the lead plant, under the guidance of the developing design bureau, works out the tooling and process problems of producing the design and does the first production run. This plant is then responsible for transitioning the production technology and helping the second plant to start.[468] The change-control approval process for the second plant runs through the lead plant, which further complicates the process of change incorporation.[469]

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463 Valenta and Potter, p. 101.
464 Agursky, p. 11.
465 Alexander, 1973, p. 430.
466 Alexander, 1973, p. 428.
467 Kehoe and Brower, p. 709.
468 Westwood, p. 315.
469 Westwood, p. 315. Studies show that there is often a marked quality difference between items from the two plants; items made on the "secondary startup line often are not of the quality of the first line's products."

INDUSTRIAL WAR-FIGHTING CAPABILITY

Having looked at the Soviet weapons-acquisition process in peacetime, one may question how the Soviet production system would perform in an industrial war-fighting environment. To answer that, we must first answer three questions: How would the Soviets mobilize and use their existing forces? How would the Soviets mobilize their industry to support their forces? To what extent could the Soviets sustain that mobilization effort in an industrial war-fighting environment?

MILITARY MOBILIZATION

The Soviet Union relies on a strategy of mass conscript armies, a European military tradition developed in the last century. Under that tradition, all young men of a nation are drafted between 17 and 18 years of age, given military training (usually 2 years), and then released to serve in the reserves, subject to call-up in the event of war. The Soviets follow this tradition and maintain a large peacetime conscript army. Except for a permanent officer cadre, the army is mostly in a training status.

The training army that is in existence at any given moment is not the one with which the Soviets plan to fight a conventional war. Most Soviet divisions, in fact, are considerably under strength and not combat ready, which is not surprising since their main peacetime function is training.

Soviet divisions are divided into three categories during peacetime: Categories A, B, and C. Category A units are manned at 75 to 110% (assault) strength in both men and equipment. Soviet units outside the Soviet Union are usually stronger than Category A formations inside the Soviet Union, as in the case of the first-line Soviet units stationed in Eastern Europe.

Category B units are manned at 30 to 70% strength, the average being slightly more than 50%. Equipment is close to full strength, but less so than Category A divisions because more equipment is in storage. These divisions are deployable within 30 days of mobilization.

Category C units are manned at 5 to 30% strength and usually have only 30 to 50% of their required equipment available, mostly in storage. Most of the major combat items are present, although they are older models. Some divisions in this category are missing entire regiments. Divisions in this category are not normally considered deployable until between 90 and 180 days after mobilization, although some of the Soviet divisions that invaded Afghanistan in 1979 may have been Category C units that were mobilized in 60 days.[470, 471]

In the event of war, the Soviets intend to fill out the divisions with reservists on mobilization to bring the divisions up to full strength. To facilitate this process the Soviets organize their reservists in three categories depending on age: the first group is under 35 years old, a second group ranges in age from 35 to 45 years, and a third group is formed of reservists from 45 to 50 years old.[472] Some of the reservists, probably the younger age group, receive regular refresher military training. The Soviets release no data on the percentage of those in the reserves that receive military refresher training, nor on the amount of training given.[473] It is believed that such training varies from republic to republic.[474] One of the great planning imponderables of World War III is that the West doesn't know how good the Soviet reservists will be when they are mobilized.

The Soviets expect to use the reservists to flesh out the under-strength units on mobilization, so the normal peacetime army strength of a little more than 1.5 million men is deceptively small[475] and does not represent the conventional land-force strength available to the Soviet Union. The Soviet peacetime strength consists of 183 active divisions plus a large number of independent brigades, regiments, and battalions. Bringing these existing units up to full strength on mobilization would raise the operational army land-force strength to 4,100,000 men.[476] It is estimated that

> the Soviet leadership should be able to mobilize 2 to 3 million men in 24 hours. An equivalent number again could be called within a 48-hour period, approximately doubling the regular peacetime force of between 4.5 and 5 million men. This should give the Soviets a total of between 9 and 11 million men in uniform within 2 full days. Since in peacetime, the Soviet Union has at least 9 million men in the reserves who have had military service within a 5-year period, the Soviet Armed Forces probably could reach 13 to 14 million in less than 10 days, if such numbers were needed.[477]

It is not the 1.5 million-man peacetime Soviet army (or training force) that concerns the West but rather the tremendous mobilizable pool of trained manpower and equipment, which represents a threat to Western Europe and NATO. In the days before World War I, this endless pool of manpower was dubbed the "Russian Steamroller." The vision of the Russian czar's endless reserves rolling over Europe shaped the diplomacy of the age and kept the lights burning all night in the war ministries of Europe. In a grand strategic sense,

470 Isby, p. 28.
471 Suvarov, p. 138.
472 Scott and Scott, p. 322.
473 Scott and Scott, p. 323.
474 Scott and Scott, p. 323.
475 Suvarov, p. 138.
476 Suvarov, p. 138.
477 Scott and Scott, p. 326.

the Soviet army, by integrating reserves with active units and providing full equipment, is an effective producer of armor-mechanized divisions. Not at all suited for overseas expeditions, and dependent upon rail transport for movements between different fronts separated by several thousand miles, these divisions are nevertheless powerful instruments of offensive war, useable wherever the Soviet Union may seek to enlarge its empire.[478] It is the reality of this huge, mobilizable Soviet conventional army that determines counter-mobilization rates of NATO's conventional force reserves, sea and air replacement rates of war reserve replacement forces from the United States, and tactical nuclear threshold scenarios to prevent conventional defeat of the NATO land armies.[479] All of these matters are beyond the scope of this document; our concern is where and how the Soviets plan to get the arms and equipment.

Soviet policy calls for training army personnel on a small portion of a unit's equipment, leaving the majority of the equipment in storage.[480] "In this way operational vehicles and spares held for replacement can be maintained in good condition against the outbreak of war."[481] These stores are enormous by Western standards. Their size results from the Soviet preference for quantity over quality and the Soviet policy of keeping older equipment. Though some Western observers contend that the Soviet military establishment never throws anything away, the Soviets do in fact have a precise method for determining when to throw away old equipment and when to put it in deep long-term reserve storage (mothballed). This method is driven by the Soviets' state accounting system, under which military equipment and armaments are treated as capital stock and are depreciated at a high rate over 15 years[482, 483] at which point the equipment's "book value" is totally depreciated and the equipment is declared worn out for accounting purposes. This equipment may have moved from unit to unit during its life, being passed from front-line units when it was new to Category C reserve units at the end of its life. Most of the equipment has been little used and therefore has a high residual (or scrap) value in Western terms. The Soviets put the equipment in mothballs for the rest of its "useable life," which is considered to be 30 years.[484] Useable life in the Soviet state accounting system is defined as six 5-year plans.[485] In this way

> The U.S.S.R. has placed in storage major weapon systems and other war-fighting equipment. These items include tanks, armored personnel carriers, field artillery, air defense weaponry, and maintenance, engineer, signal and other types of support

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478 Luttwak, 1984, p. 119.

479 Laurence Martin, *NATO and the Defense of the West* (New York: Holt, Rinehart and Winston, 1985). A general discussion of this issue.

480 Friedman, 1979, p. 65.

481 Friedman, 1979, p. 65.

482 This is another reason that fielded Soviet systems seem to have a 15-year life.

483 Westwood, p. 145.

484 Westwood, p. 145.

485 Westwood, p. 145.

equipment. Many of these systems, while older models, are capable of performing effectively in combat. They would be used to replace losses and create additional combat and support units. This equipment thus constitutes an important addition to Soviet military power.[486]

This deep-storage mothballed equipment is a necessary adjunct to another Soviet war-fighting policy that is largely hidden from public view: the mobilization-only division system,[487] as it is termed in the West, or the "second formation" system,[488] as the Soviets refer to it.

In peacetime, every divisional commander has two deputies;[489] one carries out his duties continuously, and the other is an understudy with the designation (widely known but not officially acknowledged) "Divisional Commander Second Formation."[490] This dual-deputy pattern applies to the divisional chief of staff, and on down the line through the regiments all the way to the battalion commanders.[491] If a war breaks out and a division receives orders to move to its operational zone, the divisional commander takes with him "only one deputy—the officer who has been carrying out his function, with all its responsibilities, in peacetime. His chief of staff and his regimental commanders also have only one deputy apiece. The battalion commanders have no deputies."[492]

> So, the division leaves its camp at full strength, with all its soldiers and equipment. If it has less than its complement of soldiers and junior officers, it will be brought up to strength as it moves to the operational zone. The absorption of the reservists has been very carefully worked out. However, after the departure of the division, the military camp is not left empty. The colonel who functioned as deputy to the division's chief in peacetime, has remained there. There too, are 6 lieutenant colonels, who were the deputies of the regimental commanders; the deputy battalion commanders; and one-third of the platoon commanders, who now become company commanders. Thus, an entire command staff remains in the camp, their previously secret titles become overt. Within 24 hours this new division receives 10,000 reserve soldiers who have been called to duty, pursuant to the mobilization order, and the military camp from which one division has only just set out is already occupied by a new one. Unquestionably, of course, the new division is inferior to the one which has just departed for the front.[493]

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486 Schnepf and O'Leary, p. 33.
487 Isby, p. 28.
488 Suvarov, pp. 142-144.
489 Suvarov, p. 142.
490 Suvarov, p. 142.
491 Suvarov, p. 142.
492 Suvarov, p. 142.
493 Suvarov, p. 143.

The reservists who make up the bulk of the division have forgotten a lot of their military skills and have grown soft on civilian living. They will have to be whipped into shape and retrained by the permanent officer core, but their division is in being.

Where does the equipment for this new division come from? It comes from the reserves of older equipment that the Soviets have put in mothballs.[494] As Soviet units are equipped with new weapons, the previous generation is put in mothballs for the "second formation divisions."[495, 496]

The Soviets have integrated this older equipment as part of their reserve call-up planning. They plan to match the reservists with the equipment on which they were trained 8 or 10 years earlier.[497] This, it is felt by the Soviet General Staff, will reduce the formation training time to a minimum. While these second formations "are old-fashioned and they don't bristle with top-secret equipment, . . . it costs absolutely nothing to maintain 150 of them in peacetime, and the arrival of 150 divisions, even if they are old-fashioned, at a critical moment, to reinforce 150 others who are armed with the very latest equipment, could nonplus the enemy and spoil all his calculations. That is just what happened in 1941."[498] The German generals knew nothing about the "second formation" system[499] in 1941 and badly miscalculated the size of Soviet mobilizable strength. By mid-August 1941, the Germans found themselves facing 360 divisions instead of the 141 for which they had planned.[500] This system is credited with saving the Soviet Union from defeat in World War II and is still in use today.[501]

The Soviets plan to move their army into battle in waves. First into battle will be the Category A units, well equipped and reasonably ready for combat. Then will come the Category B divisions (brought up to strength with reservists) approximately 30 days after mobilization.[502] Then will come the Category C divisions made up largely of reservists and older equipment.[503] Most of these Category C units are held in semiactive status in the interior of the Soviet Union, and it would take them 90 to 120 days to become fully

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494 Suvarov, pp. 143-144.

495 Suvarov, p. 144.

496 U.S. Department of Defense, 1986, pp. 75-76. This practice is true only for Soviet Category B and C units. The Soviets actually use a "trickle-down" process in their equipment allocation; high-priority formations such as Soviet forces in the Western TVD (theater of military operations) are usually the first to receive modern equipment. As the older material is replaced, it is sent to other TVDs, to lower-priority units in the U.S.S.R.'s interior. This equipment may replace still older equipment, which is then sent to deep mothball storage for the second-formation units.

497 Suvarov, p. 144, and Donnelly, p. 1297.

498 Suvarov, p. 144.

499 Suvarov, p. 142.

500 Suvarov, p. 141.

501 Suvarov, p. 142.

502 Isby, p. 28.

503 U.S. Department of Defense, 1987, p. 76.

operational and arrive on the battlefield. Nonetheless, they would have formidable capabilities when employed as fresh forces late in a war against an enemy that is exhausted or has experienced heavy losses.[504]

Next will come the mobilization-only divisions of the second-formation system with their older reservists and their antiquated but still functional equipment. "Mobilization-only divisions are unlikely to be deployable even for second-line duties before 180 days after mobilization."[505]

What does all this add up to, in terms of men and military potential? No one, probably including the Soviets, really knows, but one can do some gross calculations if one chooses to believe that the Soviets can carry out their troop mobilization plan. The General Secretary of the Communist Party of the Soviet Union could expect to have, 6 months after ordering mobilization, a fully mobilized and equipped ground combat army (of somewhat uneven quality) of 366 divisions, composed of 5,124,000 men. (This is the only army that has a peacetime complement of 1.5 million men.) The other four services would also increase correspondingly in size, resulting in a total mobilized force of probably 12 to 14 million men.[506]

Can the Soviets maintain and support a military establishment of that size? Can they sustain such a force for the short term? Can they effectively transition from a peacetime weapons-acquisition process to an industrial mobilization warfare mode?

The answer to the first question is probably yes. In World War II, the United States fielded and maintained a military establishment of 13.5 million men under full mobilization conditions. There is no reason to believe that the Soviets could not do that today. Their economy is larger today in absolute terms than ours was then.[507] Furthermore, the Soviets' production record in World War II is impressive. In spite of having a large portion of their most productive industrial zones overrun in the initial German advance, the Soviets were able to mobilize their remaining resources effectively and produce a prodigious amount of military equipment, including 102,000 tanks,[508] 116,000 aircraft,[509] and 422,000 artillery pieces[510] (not counting mortars). The tank production is significant, because the Soviets

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504 U.S. Department of Defense, 1987, p. 76.

505 Isby, p. 28.

506 Scott and Scott, p. 326.

507 This statement is the author's assumption; a detailed discussion is beyond the scope of this document. Three excellent reports on the subject by the Hudson Institute are listed in the bibliography.

508 Suvarov, p. 182.

509 Mark Harrison, *Soviet Planning in Peace and War, 1938-1945* (Cambridge, England: Cambridge University Press 1985), p. 250.

510 Harrison, p. 250.

were able to increase overall tank production by 700% within the first year after the German invasion.[511]

The answer to the second question probably depends largely on the size of the Soviet ammunition reserve and the level of combat activity. If the war becomes a Sitzkrieg, either with or without a short-term active-combat phase at its beginning, the answer is probably yes. If, however, any significant portion of this huge military establishment becomes involved in protracted combat, the Soviet ability to sustain the force is in serious doubt. Soviet forces have poor overall logistics capability and are largely dependent on rail transport over any long distance; the ammunition consumption and wastage of modern conventional war will be enormous.

The answer to the third question is described at length in the next section, Industrial Mobilization. However, the question of how the Soviets plan to perform this transition is germane and will be discussed here.

The last two World Wars and, to a certain extent, the Korean and Vietnam conflicts, demonstrated that modern combat cannot be sustained for any period of time without transitioning to an accelerated industrial output to support it. It is impossible to wage a modern war for any length of time relying on stockpiles of weapons and materials that were created in peacetime.[512, 513] The transition from initial combat and the coming on line of new industrial production to sustain the combat forces are the most critical time problem in modern industrial mobilization warfare, and several studies have been conducted in the West to evaluate the ammunition and equipment stockpile size necessary to bridge this gap. The usual result of such studies is to find that the West's ammunition and equipment reserves will become exhausted before the industrial transition is accomplished.

The Soviets have the following scenario for the transition to industrial warfare. The inevitable clash with NATO on the plains of central Europe will consume the West's ammunition reserves and destroy the existing weapons set of the NATO high-technology forces. This effort will also consume the initial weapons set of the high-caliber Soviet Strike Armies of the Western TVD (theater of military operations). In fact, final victory may well be obtained by the Category B divisions after all of the Western-facing Category A Soviet force strength and a significant part of the Category B force strength have been consumed. This will leave the remaining Soviet Category B forces with their older equipment to fight around the periphery while the Category C and mobilization reserve divisions of the second-echelon formation act as pacification and occupation forces in the newly conquered territory, permitting the Soviets to carry out limited military operations during the period of transition to industrial warfare and resupply of the Soviet army.

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511 Harrison, p. 82.

512 Progress Publishers, *War and Army*, p. 220.

513 Even the brief Persian Gulf conflict saw allied equipment reserves drop to critically low levels.

On the other hand, a defeat of the Soviet attack by the West would undoubtedly consume all of the Category A and most of the Category B forces. The Category C forces and mobilization-only reserve divisions of the second-formation system would be expected to hold off the exhausted and decimated Western armies during the period of transition of Soviet industry to industrial mobilization warfare. In short, the Soviet Category C reserve divisions with its older equipment and the mobilization-only divisions of the second-echelon system with their antiquated equipment are the Soviets' means to bridge the gap between the initial combat phase of war and the onset of industrial mobilization production of new armament supplies. Western observers may scoff at the concept of using antiquated equipment as a method of transitioning the gap between the outbreak of war and the onset of new industrial weapons production, but they should not do so too loudly. The Soviets at least have a plan; the West does not.

INDUSTRIAL MOBILIZATION

It is difficult to adequately discuss the Soviet industrial mobilization policy in a study of this nature,[514] which is concerned primarily with the Soviets' peacetime weapons-acquisition system. Nevertheless, some comments on the effect of Soviet wartime-industries mobilization planning on the peacetime weapons-acquisition and -production system are required.

The Soviet economy is much more a "war economy" in peacetime than is the West's, partly by design and partly because of the way the Soviet economy works. The Communist Party, when it laid out the basic plan of industrialization for the country in the 1930s, deliberately set about designing a military mobilization capability into the economy. The new civilian industries that were planned and set up had been designed with military production in view,[515] establishing a tradition that has been carried forward to this day. Since the Soviet economy is run as a centrally planned economy even in peacetime,[516] the system works like a Western wartime economy. Goods are allocated by need and not (as in a Western peacetime economy) by ability to purchase.

Because it is easier for the central command authority to encourage wartime industrial mobilization planning as part of the overall economy, the Soviets do more wartime mobilization planning than the West. This planning affects plants, particularly military ones, and their operation even in peacetime. For example, the military factories' tendency toward self-sufficient production is influenced by the importance the Soviet

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514 Some excellent studies on the subject have been done and several are listed in the bibliography of this report. Those done by the Hudson Institute are particularly worth reading.

515 Amann, Cooper, and Davies, p. 281.

516 Something that the West only does in wartime.

system places on factories being able to sustain production in wartime, an influence that dictates few external suppliers and dependencies.[517]

The wartime-planning attitude also appears in the way the Soviets plan and use the capacity of their military-production-ministries' facilities. A large part of Soviet defense industry has been operated at about 50% of capacity for military production for some years,[518] thus leaving a large part of the capacity available for accelerated production in the event of an emergency expansion requirement.[519] However, this does not always mean leaving the plants' excess capacity idle, because the Soviets promote a policy that they call "military assimilation" (assimiluatsiya).[520] This policy has two dimensions: first, "the use of spare capacity at military factories for the production of civilian items technologically related to the basic military products so as to maintain appropriate skills; and secondly, the creation of conditions permitting the manufacture of military material at the many civilian enterprises in the event of war."[521] This policy, which has been reaffirmed periodically through Party and government decrees,[522] provides a means of employing the reserve capacity of military factories that could be transferred to military-related production in the event of need.[523] As a result of assimiluatsiya, most military production facilities in the Soviet Union also produce civilian goods of some type. For example, the giant Nizhnii-tagil Uralvagonzavod tank plant also produces railway freight cars.[524] How pervasive is this practice? "Speaking at the 24th Congress of the Communist Party of the Soviet Union (CPSU), in March 1971, Party General Secretary L.I. Brezhnev revealed that 42% of the volume of production of the defense industry served civilian purposes."[525]

The policy of having the defense industry produce consumer goods to provide a "buffer production" that will make use of idle capacity in the industry[526] probably adds significantly to the civilian economy of the Soviet Union. The policy also provides

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517 Westwood, p. 303.

518 Westwood, p. 100.

519 This under use is similar to that found in some segments of the Western armament industry, where production runs at only a fraction of capacity. For example, munitions plants (shell and ammunition facilities) often run at only about 20% of their one-shift capacity in peacetime. Explosive production facilities often run around 10%, while aircraft assembly plants often run at only 10 or 15% of capacity, because no government wants to buy their full output in peacetime. Under use in the USSR is probably masked to a greater extent than in the West by the Soviets' higher use of the engineering industry for civilian production.

520 Amann and Cooper, 1986, p. 33. The term was coined by S. Ventsov, head of the mobilization sector of the Red Army staff in the mid 1920s.

521 Amann and Cooper, 1986, p. 33.

522 Amann and Cooper, 1986, p. 47.

523 Amann and Cooper, 1986, p. 42.

524 Amann and Cooper, 1986, p. 33.

525 Amann and Cooper, 1986, p. 31.

526 Amann, Cooper, and Davies, p. 309.

considerable management flexibility in closing down military production programs without causing major personnel layoffs and associated labor unrest.[527]

Many observers believe that assimiluatsiya provides the Soviets with "the capability for rapid expansion in wartime,"[528] or in Western terminology, "surge capability." However,

> while it is probably the case that much of the capacity of the defense industry devoted to civilian purposes is regarded as potentially available for military production (some at relatively short notice, providing a surge capability), it may now be incorrect to assume that all such capacity is regarded as a reserve for military purposes.[529]

The problem referred to here is the dispensability of the civilian product to the economy. If the military plant's civilian product has become so important to the civilian economy that it cannot cease being produced without causing shortages of the product in the civilian economy, then the plant may not be capable of being converted to military use. The Soviet economy has, as noted, a chronic overall shortage of almost all industrial supplies. The sudden disappearance of a significant number of products could produce economic chaos.

Two factors restrain the Soviet economy and make it far less capable of rapid expansion than are the capitalist economies of the West.[530] The first is the rigidity of the centrally planned economic system,[531] the problems of which have already been discussed. The second is a derivative of the first. The central planners try to run the Soviet economy at a maximum rate of use; evidence exists that they actually try to run it beyond its theoretical capacity. This high level of use, taken with the economy's inherent rigidity, makes it much more difficult to bring the "military reserve capacity" on line, to surge, than might be expected.[532] The Soviet Union has been historically a one-party political state, and the experiences of Germany and Italy during World War II shows that internal dynamics of such one-party states can act as a powerful restraint on mobilization and conversion of industrial facilities.

These rigidities and restraints notwithstanding, the Soviets would undoubtedly be able to convert a large part of their reserve military-production capability into active armament production in some reasonable period of time, though with more disruptive effect and industrial dislocation than is generally believed. Western studies on the subject have generally concluded that it would take 9 to 12 months for the Soviets to convert their

527 Amann, Cooper, and Davies, p. 310.
528 Schnepf and O'Leary, p. 43.
529 Amann and Cooper, 1986, p. 43.
530 Friedman, 1979, p. 65.
531 Friedman, 1979, p. 65.
532 Friedman, 1979, p. 65.

military industrial reserve capacity and bring it on line.[533] This would amount to a surge capability that would probably result in an armament production output of from 225 to 250% of the peacetime production rate at the end of the 12-month surge period. This is not a full mobilization rate for the Soviet economy but would represent a significant short-term increase in armament production output, considering the already high level of production output.

The Soviet Union engages in two other activities in relation to long-range mobilization planning that have a moderate effect on the peacetime acquisition system: the design of mobilization model equipment and the management of military districts.

The Soviets believe in quantity and believe in planning for the production of that quantity in a wartime environment. Therefore, design bureaus must develop stripped-down high-rate mobilization models of their production designs.[534] These models are known as "monkey-models" in the Soviet armament design world.[535] The onkey-model is a system that has been simplified in every conceivable way and is intended for production in wartime only.[536] As a result, "Many items produced by the Soviets can be simplified by removing technologically sophisticated subsystems, resulting in [a soviet] ability to produce larger quantities of less complex weapons."[537] The monkey-model is made by removing these compartmentalized features and producing a weapon system without such items as night-vision equipment, stabilized guns, and computerized range finders, and supplying instead simplified radio and optical equipment and manual gun-laying equipment.[538] The monkey-model, or some variant of it, is sometimes used as the export version of the system to Third World countries. This practice often results in some confusion, because the two variants may look very much alike from the outside, and cursory examination of an export variant may lead to erroneous conclusions about the quality of Soviet equipment.[539]

The military district's role in long-range mobilization also affects the peacetime acquisition system. "Soviet combat forces, other than the Strategic Rocket Forces and Troops of National Air Defense, are deployed primarily in sixteen military districts: four groups of forces abroad, and four fleets."[540] These military districts serve a dual tactical and mobilization purpose. At a tactical level, military districts are the training and housekeeping components of the Soviet armed forces.[541] In the event of war, those forces assigned to a military district would move out as a body to form a military front, leaving behind cadres to reestablish the military district forces through mobilization of additional

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533 Westwood, p. 100.

534 At exactly what phase of the development cycle this is done, the author does not know. It may be that it is only done on systems that have been accepted for series production.

535 Suvarov, p. 184.

536 Suvarov, p. 184.

537 Schnepf and O'Leary, 1984, p. 43.

538 Suvarov, p. 184.

539 Suvarov, pp. 184-185.

540 Scott and Scott, p. 173.

541 Scott and Scott, p. 177.

men and equipment.[542] In this way the military district acts as home base for recruitment and supply of the front, in a manner similar to the regimental base system of the British army, but on a much larger scale.

The economy of each of the 16 military districts has been organized into a self-contained manufacturing region that specializes in the production of a particular limited group of weapons, as illustrated in Figure 5.[543]

1. TACTICAL AIRCRAFT
   AIRCRAFT ENGINES
   STRATEGIC AND DEFENSIVE MISSILES
   MISSILE ENGINES AND MOTORS

2. STRATEGIC AIRCRAFT
   AIRCRAFT ENGINES
   MAJOR SURFACE COMBATANTS

3. ARMORED VEHICLES
   TANKS

4. STRATEGIC AND DEFENSIVE MISSILES
   MISSILE ENGINES AND MOTORS
   MAJOR SURFACE COMBATANTS

5. MAJOR SURFACE COMBATANTS
   SUBMARINES
   TANKS
   AIRCRAFT ENGINES
   MISSILE ENGINES AND MOTORS
   DEFENSIVE MISSILES

6. TACTICAL AIRCRAFT
   MISSILE ENGINES AND MOTORS

7. TACTICAL AIRCRAFT

8. STRATEGIC AIRCRAFT

9. TACTICAL AIRCRAFT
   AIRCRAFT ENGINES
   MISSILE ENGINES AND MOTORS
   ARMORED VEHICLES
   TANKS
   ARTILLERY, SP GUNS AND MULTIPLE ROCKET LAUNCHERS

10. MAJOR SURFACE COMBATANTS
    STRATEGIC AND TACTICAL AIRCRAFT
    AIRCRAFT ENGINES
    STRATEGIC MISSILES
    MISSILE ENGINES AND MOTORS
    ARMORED VEHICLES
    ARTILLERY, SP GUNS AND MULTIPLE ROCKET LAUNCHERS

11. SUBMARINES
    TACTICAL AIRCRAFT
    ARMORED VEHICLES

12. STRATEGIC MISSILES
    TACTICAL AIRCRAFT

13. MAJOR SURFACE COMBATANTS
    SUBMARINES
    STRATEGIC MISSILES
    TACTICAL AIRCRAFT

14. AIRCRAFT ENGINES
    STRATEGIC MISSILES
    DEFENSIVE MISSILES
    ARMORED VEHICLES
    ARTILLERY, SP GUNS AND MULTIPLE ROCKET LAUNCHERS
    TANKS

FIGURE 5. Major Soviet Manufacturing Areas.

542 Scott and Scott, p. 176.
543 U.S. Department of Defense, 1981, p. 10.

The arrangement of manufacturing regions affects the location of military production plants in peacetime and sometimes even the selection of a given plant to produce a particular system. This specialization of military production by the military districts has its most important impact in wartime. Soviet writers emphasize that "one of the most important tasks of the military districts is mobilization work."[544] The Soviets intend to turn each military district into an independent industrialization mobilization zone, organizing all the industry in that zone in such a way as to direct that industrial capacity to the building of the district's specialized military goods.

SUSTAINABILITY

The Soviet Union, like the United States, has built a peacetime weapons-acquisition system that effectively matches weapons requirements with industrial capacity, technology, manpower capability, social environment, and political condition. The Soviets have also planned extensively for converting this peacetime weapons-acquisition establishment into a wartime military manufacturing base. Their planning for conversion is rational and will probably be effective, though historical precedent indicates that executing such planning will probably be more difficult than is presently envisioned.

Can the Soviets sustain a major conventional war and its associated industry mobilization warfare? We don't really know, and only an undesirable turn of future events resulting in a third world war can tell us. However, several points work in the Soviets' favor. Their economy is more self-contained than any other in modern industrial history and cannot be blocked as was done with Germany in the last two world wars. Their industrial base is one of the largest in the world, larger in absolute terms today than any industrial economy mobilized for war in the past. The Soviet economy is also built specifically for war, much more so than is the more open and flexible economy of the West.

These industrial advantages are compounded by the fact that in a future conventional war the Soviet industrial facilities may be invulnerable. The theory of strategic bombing, developed in the 1920s by General Douhet, used by all powers to fight World War II, and carried forward into the early nuclear age, may be inapplicable to a conventional war fought under a nuclear umbrella. The fear of nuclear escalation may prevent either power from sending out weapons to attack industrial targets or other targets deep in the enemy's homeland. Furthermore, the technology for doing so today, with conventional weapons, is much more complicated than in World War II. Modern air-defense technology makes the idea of the thousand-plane bomber raid impractical. By about the third raid, the bomber fleet would no longer exist. With all due respect to

544 Scott and Scott, p. 177.

intercontinental ballistic missile (ICBM) technology, these weapons are the most expensive method of delivering conventional high-explosives ever devised by man. Furthermore, studies of World War II strategic bombing show that carpet bombing of civilians is ineffective, and the accuracy of an ICBM isn't good enough for anything else; it depends on a nuclear warhead for its effectiveness and economic viability. Precision attacks against a single key industry, using new precision guided munitions such as a cruise missile, stand a better chance of causing economic disruption. World War II strategic bombing showed that a concentrated attack against a single key element of the industrial structure, such as ball bearings or oil, had greater economic effect than randomly spreading the bombs around.[545] However, precision attacks are still a high-risk strategy because of the danger of escalation and questionable chance of success. It is unlikely that the economic-warfare analysts can identify any element in an economy the size of the Soviet Union's that is so vital, nor is it likely that any given target set will be small enough that its attack by extremely costly advanced high-technology weapons will be economically feasible for the West.

It is possible that the new inability to attack by strategic bombing, imposed by nuclear deterrence rather than by technological shortcomings, has put the world back where it was in World War I, with the combatants unable to attack each other's civilians and their associated industries, thus producing a situation where to be victorious army must defeat army in the field. Under such conditions, the Soviet military production base will be able to sustain forces in the field for an extended period of time, and probably do so better than the West can, at least initially. That could make for a very long war.

545 This information was not known until German and Japanese files became available and industrial leaders were interviewed by U.S. and British intelligence officers at the end of the war.

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