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Preparation for Production of Soviet Weapons

A Research Paper

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Preparation for Production of Soviet Weapons

A Research Paper

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Preparation for Production of Soviet Weapons

Scope Note

The US Intelligence Community has extensively analyzed the Soviet weapon development process, but has paid comparatively little attention to the measures the Soviets take to prepare the manufacturing base for series production. This paper addresses steps the Soviets have taken to ensure that preparations for production are undertaken in parallel with weapon development and do not add to the total weapon acquisition time. It also assesses the benefits and risks associated with the Soviet strategy.

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Preparation for Production of Soviet Weapons

Summary

Information available as of 30 April 1987 was used in this report.

Since the late 1960s, the Soviets have used a highly structured, and quite successful, process to organize and manage the acquisition of weapons. One management system covers all phases of a weapon's design, engineering, and testing Another covers the design, engineering, installation, and testing of manufacturing equipment and facilities, or, in Soviet parlance, technological preparation for production (TPP).

The Soviets have issued more than 100 sets of technical instructions to govern TPP. These instructions direct the coordination among weapon designer, series production plant, and the dozens of plants that will supply machinery, materials, components, and subassemblies. For a major weapon program, facilities usually must be expanded or new ones constructed, and thousands of tools, dies, jigs, and fixtures must be produced and installed.

All countries begin TPP when a weapon is still in development, but there is considerable latitude in deciding when to make the heavy resource commitments for building and equipping facilities that can cost the equivalent of $500 million to $1 billion. The USSR typically initiates these outlays when the weapon is being designed—as much as five to 10 years before it is ready for series production. This practice is intended to ensure that plants can initiate series production as soon as the weapon completes testing and is accepted by the military. In the United States, a production decision is made only after validation of research and development or "critical design review." Because US companies do not spend substantial funds on production preparations before this point, an additional two to three years is usually required to begin series production of major weapons such as fighter aircraft

Analysis of Soviet weapon programs, as well as Soviet claims, indicates that the Soviet system has been quite effective in ensuring that total weapon acquisition time is not lengthened by TPP. We detect few gaps between weapon testing and series production that are caused by delays in plant construction or tooling; this suggests that production preparations generally are well coordinated with weapon development. In some programs, however, early commitment to TPP has caused resources to be wasted. Development delays with the TU-160 Blackjack bomber caused new production facilities to stand idle years after they were completed and equipped, and cancellation of the MI-12 Homer helicopter program occurred after its production facility had been built and equipped

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The Production Preparation System

Production of a modern weapon system requires the coordinated development and installation of thousands of tools, machines, and jigs, and even the construction of new buildings at dozens of facilities that typically participate in a major weapon program. For example, according to open Soviet literature, the tooling alone for a new heavy aircraft includes developing, producing, and installing 500 to 600 assembly fixtures, about 150,000 different templates, some 25,000 machine-tool fixtures, more than 20,000 dies for cold stamping, and over 20,000 special tools.

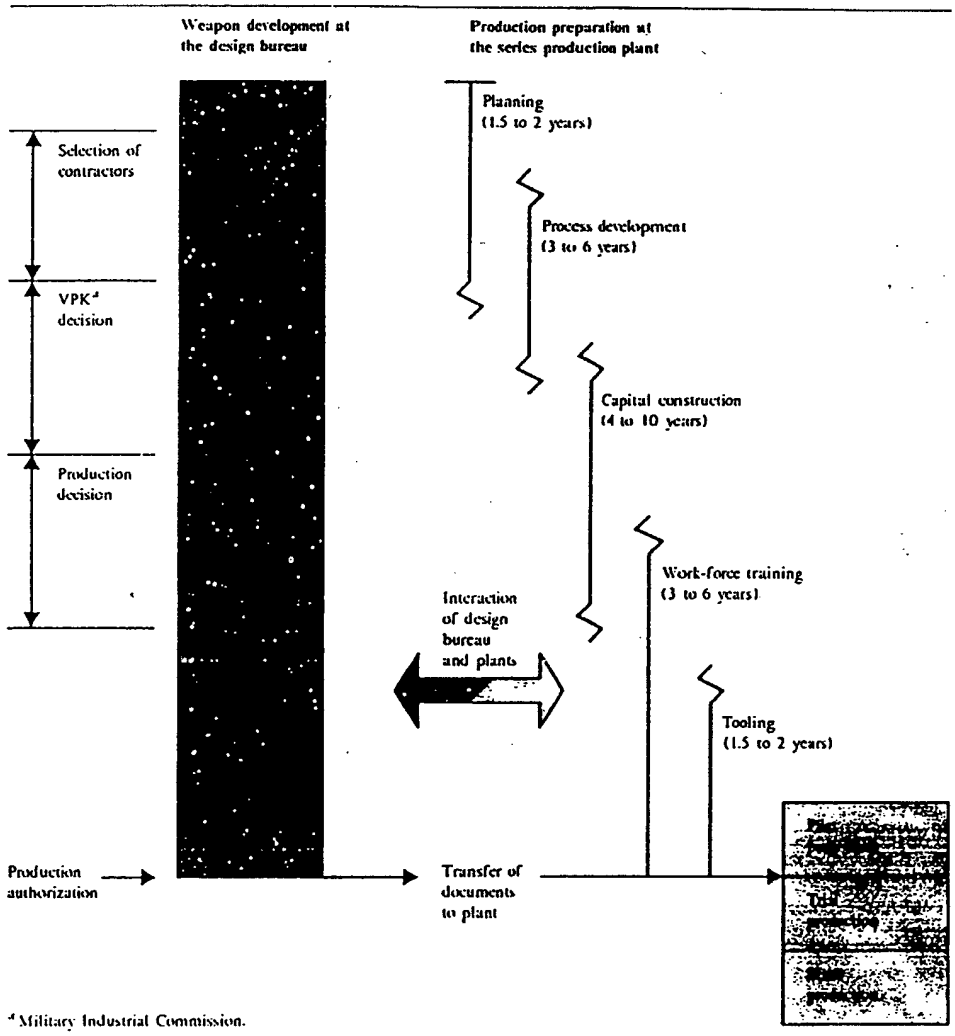
By the late 1960s, difficulties in developing and producing complex weapons led the Soviets to seek ways of controlling leadtimes and costs while reducing the time and risk associated with applying new technologies.[1] The Soviets chose to standardize further the whole weapon acquisition process—research, design, and production. In response to a joint resolution from the Central Committee and the Council of Ministers, the State Committee for Standards in 1968 published a "Unified System of Design Documentation" (YESKD) to govern product design and development.

The Soviets also developed a system to govern the associated production preparation activities. The Unified System of Technological Preparation for Production (YESTPP) organizes production preparation into five overlapping stages (see figure 1). The system is implemented through a series of state standards (GOSTs) that give specific instructions on when and how to accomplish each stage of the process. We have identified 101 GOSTs in the system (see the appendix for a list of selected titles).

Since YESTPP's original formulation, Soviet industry has sought to expedite the procurement process by placing greater stress on preparing for production during the weapon development cycle. We believe that accelerated technological preparation for production (TPP) is now used in most Soviet defense industries. In accelerated TPP:

- *Tasks are started earlier.* Under normal TPP, the plant does not begin preparation to produce a weapon until a decision to enter series production is made. Under accelerated TPP, the plant engages in the planning and development of manufacturing processes and equipment and even produces standard components and some special equipment before the formal commitment to series production.
- *Greater cooperation is required.* Accelerated TPP calls for scientific research institutes to be involved in developing the draft design of the weapon and planning manufacturing processes. In accelerated TPP the design bureau is more involved in planning for production than it is in normal TPP.
- *Additional tasks are called for.* Accelerated TPP introduces two new cooperative steps in the preparation for production: planning for advances in manufacturing processes—a joint effort by the scientific research institute, the design bureau, and the production plant; and designing structural members and special fittings—a joint effort by the scientific research institute and the plan

Figure 1
USSR: Weapon Development and Production Preparation



[a] Military Industrial Commission.

The Soviet press lauded successes at selected facilities that initially used the Unified System. The Murom Plant of Radio Measurement Instruments, for example, reportedly claimed that it was possible to reduce the volume of documentation for production preparation by 12 to 16 percent and to reduce the number of technological operations from 160,000 to 42,000. In 1975-76, such exemplary trial cases were hailed at a number of conferences and seminars devoted to explaining the Unified System nationwide. In 1985, the chairman of the State Committee for Standards claimed that Unified System standards made it possible to shorten the production assimilation time for new products by two-fifths to two-thirds, to improve product quality, and to increase labor productivity by 15 to 35 percent. Such claims probably overstate the benefits of the system but, nonetheless, indicate the Soviet belief that it provides substantial economies in the preparation for production.

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In the United States the process of preparing for weapons production is different. A weapon system usually has completed the development process before substantial funding is made available to prepare for manufacturing. Although all relevant data are collected and most production design work is completed during weapon development, funding is not available for actual construction of production facilities or for production of tooling until procurement funds are authorized and appropriated.[3] This procedure may shorten actual TPP because there is little or no uncertainty about weapon design or manufacturing processes, but it lengthens total weapon acquisition time by adding downtime between development and production.

Implementing the Process

In the Soviet system, the lead assembly plant for a weapon and the plant's major suppliers must be selected early—during the development of weapon requirements or the weapon's preliminary design stages—to allow time to accomplish thousands of TPP tasks before weapon development is complete. By the end of the preliminary design stage, the designated production plant should receive the documents it needs to formally begin TPP. These documents include the Joint Decree of the Council of Ministers and Central Committee and the Decision of the Military Industrial Commission (VPK) authorizing production preparations for the weapon. The plant also needs detailed technical descriptions from the lead designer.

During each subsequent phase of the weapon's development, production engineers are responsible for making parallel progress on production preparation. Production technology options are narrowed as the weapon design firms up. Most resources are expended on production preparation after the weapon design is "frozen" at the culmination of technical design. During the working design stage, which typically lasts three to seven years, production engineers develop detailed specifications for key production machinery and equipment, and fabricate or buy equipment for producing test articles and components. Meanwhile, tooling the supporting plants usually takes at least a

[3] *Blueprint for Tomorrow* Joint Air Force and Industry Assessment of the Aerospace Industry Base; 16 January 1984, Vol. 1; Section 2.2.3, Aeronautical Systems Division, Air Force Systems Command

Steps in the Preparation To Produce a Weapon [a]

Stage of Weapon Development	Production Preparation Activity
Technical assignment	• *Consider various ways to prepare for production.* • *Collect information on production processes and technology that might be used.* • *Coordinate the technical requirements of the weapon.*
Technical proposal	• *Identify existing parts or components that can be used in the weapon.* • *Identify alternative ways to assemble new parts and components.* • *Develop regulations for handling information on the weapon's design and its production.* • *Examine and confirm the technical proposal.*
Draft (preliminary) design	• *Assess the producibility of different parts.* • *Assess the design of parts in light of expected operational conditions.* • *Check the design for the precision and interrelationship of parts.* • *Examine and reconfirm the design documentation.*
Technical design	• *Develop a general plan for preparations to produce the weapon.* • *Develop an organizational structure for managing technological preparation for production (TPP).* • *Determine the possibility of parallel and independent assembly and inspection of parts.* • *Explore the use of standard production processes.* • *Develop requirements for computer solutions to problems.* • *Determine the accessibility and ease of maintenance of parts.* • *Check the design documentation.*
Prototype fabrication	• *Assess the possibilities for using existing assembly units, structural elements, and materials.* • *Examine the design of parts.* • *Develop a TPP information model.* • *Prepare technical and economic data.* • *Determine the machinery and tools to be used in production.* • *Determine the installation of production equipment and the organization of the workplace.* • *Lay out the production flow through the plant.* • *Manufacture special tools and equipment required for production of the product.* • *Draft programs for computer solutions to problems.* • *Correct technical documents on the basis of computer simulations.* • *Develop organizational responsibilities for the management of production.* • *Check manufacturing tolerances with tooling specifications.* • *Check the possibility of using standard machinery and tools.* • *Check the possibility of reducing the amount of machined surfaces.* • *Check the ease of inspection and repair of parts.* • *Analyze readiness for manufacturing prototype weapon.* • *Check changes in design documentation.*
Trial (pilot) and series production	• *Modify the design to meet production requirements.* • *Modify the design for ease of maintenance of parts.* • *Check the design documentation.*

[a] This outline is based on V. N. Krysin, "Tekhnologicheskaya *Podgotovka Aviatsionnogo Proizvodstva," Mashinostroyenlye,* Moscow, 1984, pp. 14-17.

year. Throughout the entire process, the Soviets place a premium on standardization, careful documentation, and use of proven manufacturing technology—all designed to ensure weapon producibility.

During the production preparation process, three milestones signal key program decisions and the commitment of substantial resources—the beginning of capital construction, the initiation of plant tooling, and the start of series production. These same milestones provide key intelligence benchmarks for the existence and status of a new weapon program.

Capital Construction. The lead production plant and its ministry may determine that the plant's existing facilities cannot accommodate a new program because it calls for unique technologies or because the scheduled production rate cannot be met concurrently with other planned production. If so, the ministry directs its project planning agency—for example, the State Institute for Design of Machine-Building Plants of the Ministry of General Machine Building—to take on the construction project. These agencies plan the construction of new buildings and the modernization of old ones, develop technical specifications, prepare blueprints, and estimate the cost of construction. After ministry approval, funds are allocated for the necessary research, coordination, and design. One of three regional ministries of the State Construction Committee usually undertakes the construction

New or renovated buildings for the support of new weapon programs are constructed according to the Soviets' Unified Modular System (UMS) from standardized structural elements made of steel or reinforced, precast concrete. Up to the 1970s, individual industrial buildings in Soviet factories did not normally mix steel and concrete structural elements and were generally described as multipurpose production buildings. Since the 1970s, however, the Soviets have made more innovative use of the UMS to construct production buildings that can accommodate changing industrial needs for advanced technology, processes, and machine tools

Nonetheless, most new production buildings in both civilian and military enterprises are still built primarily of modular, precast-concrete structural elements because they are cheaper and generally easier to obtain than steel structural elements

Tooling the Plant. Preparations for new production include developing the production processes, designing and manufacturing the production equipment, and establishing norms for material and labor expenditures. The chief manufacturing engineers of participating production plants probably estimate material and labor expenditures and sketch flow charts that show the production processes, the sequence of operations, and the required equipment.

A major portion of the development of a new weapon is devoted to the planning, designing, and fabrication of new tooling. Requirements for tooling should be distinguished from requirements for new machinery. A new weapon program may require the replacement of only a few machine tools, but it often requires extensive replacement of the tooling—fixtures, templates, dies, and jigs—used with machine tools

Soviet literature indicates that design and manufacture of production equipment can take up to 90 percent of the total TPP cycle

Figure 2

In a missile development program, the design and fabrication of "hard" tooling for series production can take half as long as the entire product development effort. Once completed, tooling is very sensitive to design changes. Changing a part by a fraction of an inch can force the redesign and manufacture of new tooling—a process that can add six months to a year to the production preparation schedule. In a program involving only a few units, such as two or three satellites, time and money can be saved by relying on "soft" tooling. Soft tooling may mean using plastics rather than metal for templates, plywood rather than steel for holding fixtures, or even making individual measurements for each fastener placement rather than using a pattern. Soft tooling, however, is usually reserved for making the initial prototypes for development testing.

Hard tooling provides dimensional consistency and repeatability in higher rate production but takes roughly 10 times longer to design, fabricate, and install and costs roughly 10 times more than soft tooling. US experience in strategic missile programs has suggested that total program tooling can add up to $350-500 million.

The trial series production run at the plant is the most crucial of all the plant's preproduction efforts. It establishes the organization of the assembly line, the assignment of workers, and the production-line technology. In this effort, earlier experience in model fabrication provides only a starting point. Trial series production—which includes changeover to hard tooling—also tests the plant's ability to meet the product's quality control requirements and to sustain the planned rate of production.

Formal changeover to series production occurs when the military customer and the designer officially accept the results of the weapon's test program and certify it for series production. This represents not only weapon certification but also validation of the associated production technology. This acceptance must be accompanied by approval of a Ministry of Defense main directorate through the military representative at the design bureau.

Every weapon undergoes at least minor design changes during the TPP. [redacted] disagreements between designer and producer over changes are not uncommon. The plant manager reportedly often tries to get a design changed to correspond to his production capabilities, insisting that this would cut costs or avoid delays. The prestige of the designer is a factor in the outcome of these disagreements. For example, [redacted]

[redacted]

Production Preparation Time:

[redacted]

[redacted]

Most often we are unable to measure precisely the duration of production preparation because we rarely detect the event that initiates TPP—the issuance of a VPK decision. We believe, however, that the time between construction startup at a new production facility and initial weapon series production—typically four to 10 years—is a reasonable indicator of time needed for TPP. This period encompasses most of the activities undertaken in the TPP process

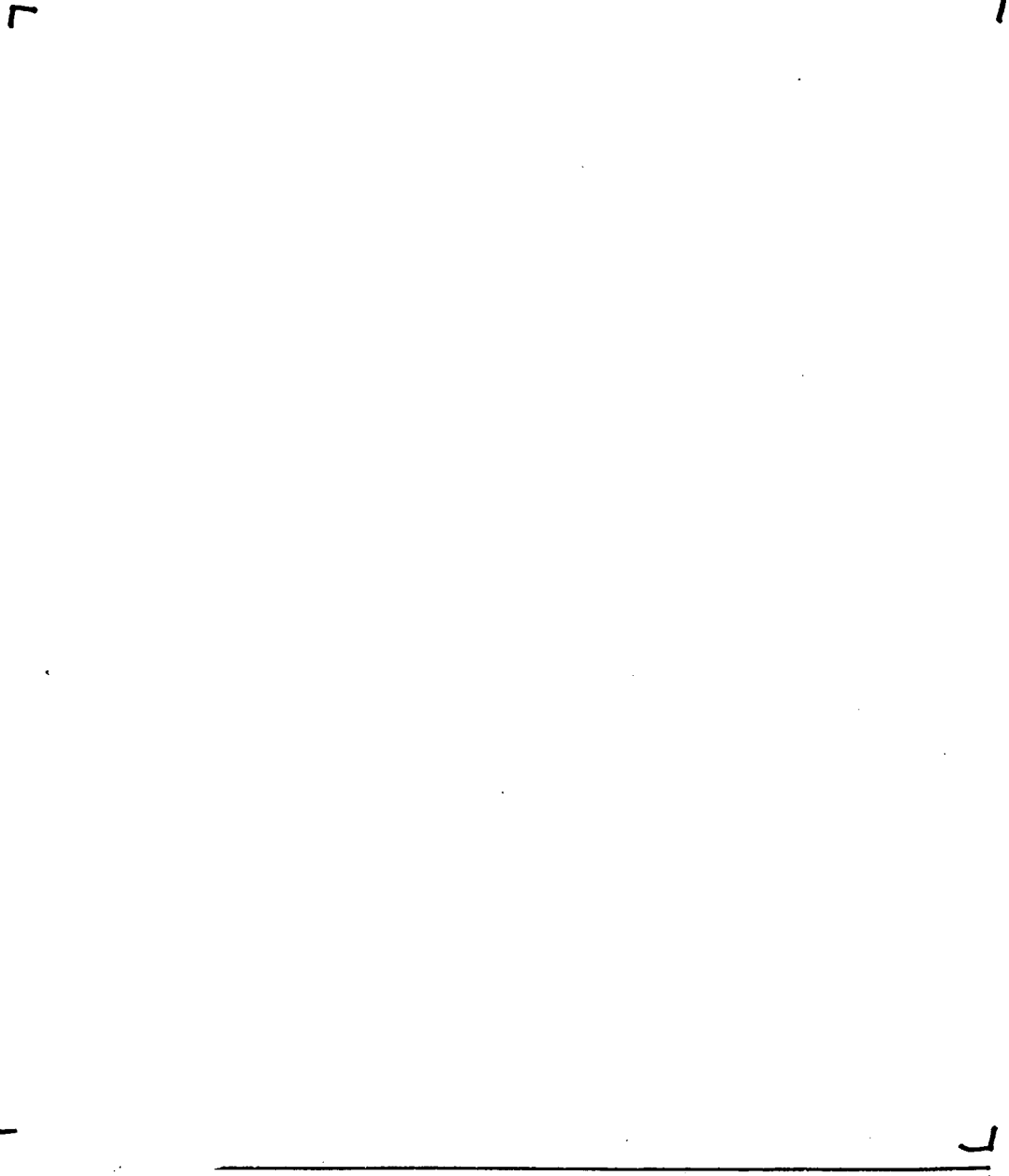
The length of the TPP usually can be established with confidence only for major weapon programs in an expanding industry. Visible evidence of production preparations is usually not available for smaller weapons, such as artillery, radar systems, and aerodynamic missiles. For these weapons, existing facilities often are adequate to handle new programs, obviating the need to erect new buildings. In other cases, we may observe construction activity but not be able to link it to a specific weapon program.

Nonetheless, we can, with reasonable certainty, associate specific construction activity with 18 major aerospace programs. [redacted]

[redacted] These 18 capital construction programs exhibit wide differences in the extent of facility expansion (from 15 to 100 percent), the initiation of construction (1960 to 1983), and the length of time required for construction and tooling (three to 11 years). The ranges in the extent of expansion and the time for construction and tooling are caused by differences in weapon requirements—particularly the degree of technological innovation required—and in the pace of weapon development (see table). Analysis of another 12 programs—

[redacted]

Figure 3



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USSR: Time Required for Construction/Tooling at Final Assembly Plants in Major Aerospace Programs

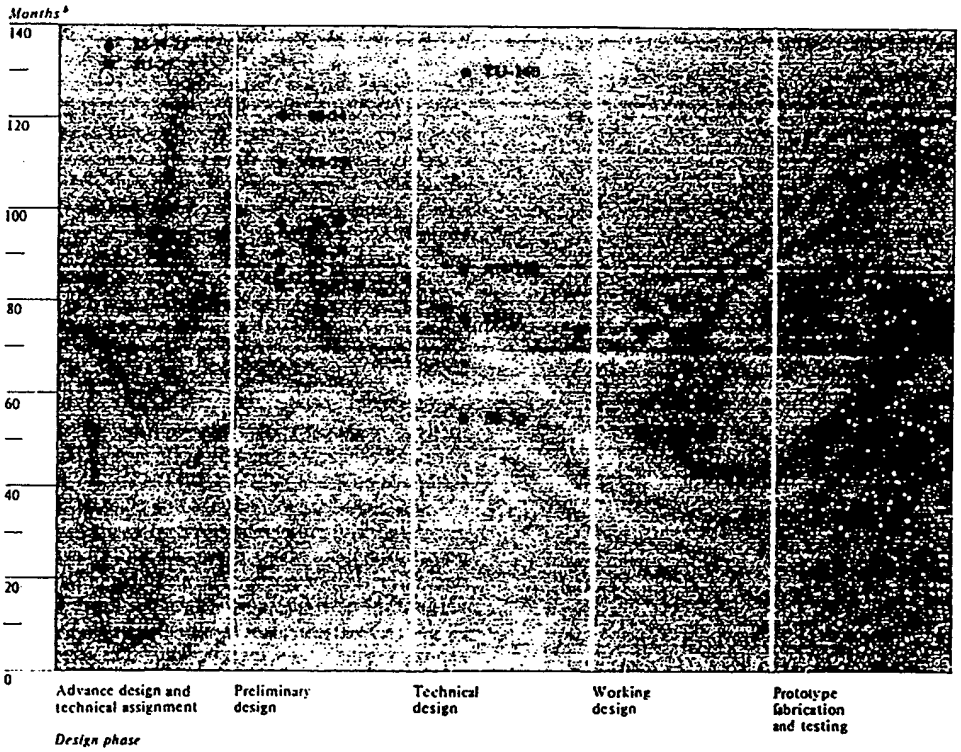
primarily tanks and ships—reveals construction and tooling times similar to those for the aerospace programs.

Although there is no simple relationship between construction/tooling time and the program initiation date, in the mid-1970s there seems to have been a breakpoint in TPP duration. Since the mid-1970s, the time spent in construction and retooling during the preparation for production has generally been longer than it was earlier. We believe this reflects Soviet efforts to intensify modernization of defense industrial facilities and introduce into production a number of very sophisticated and technologically demanding weapon systems, like the TU-160 Blackjack bomber. Our analysis suggests that during the 1970s Soviet defense industries received a growing share of investment in the Soviet machine-building sector.

Although problems with weapon design explain a portion of the longer time for some of the systems, like the SU-27 interceptor, we believe that preparation for production of these more demanding systems generally required more time than did their technologically simpler predecessors.

Analysis of the correlation between weapon development and production preparation for each of the 18 aerospace programs indicates that the Soviets generally anticipated the more demanding preparations associated with the more complex systems. Longer preparation times generally coincide with an earlier start of production preparation, measured in relation to the stage of weapon development (see figure 4).

Figure 4
USSR: Correlation Between Length of TPP[a] and Design Stage During Which TPP Is Initiated



This figure shows – for selected weapon systems – the relationship between time required for TPP (as measured by elapsed time between start of facility construction and start of series production) and the weapon development stage during which facility expansion began. The analysis indicates that the Soviets generally started TPP earlier for those systems that needed more extensive production preparation, ensuring that the plants were ready to begin series production as soon as weapon testing was completed. An exception is the TU-160 Blackjack, which is discussed in the text.

[a] Technological preparation for production.
[b] Months from start of construction to start of series production.

Analysis of the remaining 16 systems turns up only one case in which the duration of TPP was substantially longer than normal for aerospace systems, given the design stage during which TPP was initiated. For the TU-160 Blackjack, the Soviets began facility construction during the technical design stage of the development process. This stage usually precedes production by five to seven years. In the Blackjack case, over 11 years elapsed before series production began. The complexity of the Blackjack probably contributed to the long period of tooling and preparation for production.

Implications and Prospects

Soviet military planners and defense industrialists have employed TPP management techniques to ensure timely delivery of new weapons. Concurrency in weapon development and production preparation has meant that total weapon acquisition time is generally not lengthened by TPP. Concurrency probably lengthens TPP itself, however, because even minor weapon design changes in the course of the program could require adjustments in continuing tooling and process development. And concurrency risks wasting manufacturing resources, should a weapon development program be seriously delayed or canceled. In a number of cases, such as the TU-160 Blackjack bomber, development delays have caused new production facilities to stand idle years after they were completed and equipped. In other cases, such as the MI-12 Homer helicopter, a weapon program was canceled after its production facility had been built and equipped

Concurrency, by lengthening the TPP process, also increases prospects of technical obsolescence in two areas:

- *Weapon design characteristics.* An early start in TPP increases pressure on designers to make final decisions on weapon characteristics and to refrain from making changes once the original design is fixed, since changes risk disrupting established program schedules. To compensate, at least in part, the military and the defense industry have been quick to introduce variants of new weapon systems within a few years of production of the original system.
- *Weapon production technology.* Production planning also is completed early in TPP so that the machinery and tooling needed for a modern weapon system can be produced and installed on schedule. This may result in the use of production processes that are outdated by the time the weapon reaches series production. Favoring expeditious program schedules over maximum efficiency is reinforced by the Soviet incentive system, which puts a premium on using proven methods to get the product out on time.

The Soviet military has endorsed the early technology freeze and increased resource risks associated with longer TPP, in part, because it has been assured of complementary and follow-on programs to offset the risk.

Gorbachev's program to modernize the Soviet economy may generate changes to TPP in the name of economy and modernization. His pressure to produce products of the highest (world standard) quality and to economize on that production may undercut the implicit guarantee of frequent new and upgraded weapons. His demands for rapid application of new technology to improve product design and to raise labor productivity clash particularly with the practice of freezing technology early in the long acquisition cycle characteristic of advanced weapon programs. If this pressure leads to modifying established weapon TPP practices, Gorbachev could be gaining some improvement in future weapon quality and production operating economies at the cost of more delays in weapon programs.

Appendix

Selected Soviet State Standards (GOSTs) on the Unified System for Technological Preparation for Production

GOST Number	Title
14.001-73	General Rules
14.002-73	Basic Requirements for the Technological Preparation for Production (TPP)
14.003-74	Order of Organization of Scientific and Technical Development in the Sphere of TPP, Their Acceptance and Handing Over for Production
14.004-83	Terms and Definitions of Basic Concepts (for Machine Building and Instrument Making)
14.005-75	Methods of Calculating Economic Efficiency
14.101-83	Basic Rules for Organization and Management of the TPP Process
14.102-73	Stages of Designing Documentation for Organization and Improvement of TPP
14.103-73	Rules for Developing the Technical Task for TPP in the Enterprise
14.104-74	Rules for Development of Graphics Information Model for Tooling
14.201-83	General Rules for Ensuring the Technological Suitability for Industrial Production of the Design for a Product
14.202-73	Rules for Choosing an Index of Technological Efficiency of Design of Products
14.203-73	Rules of Providing for Technological Efficiency of Design of Units
14.204-73	Rules of Provision of Technological Efficiency of Design of Components
14.205-83	Suitability of a Design's Product Terms and Definitions for Industrial Production

14.301-73	General Rules of Development of Technological Processes and Choice of Means of Obtaining Technological Equipment
14.302-73	Types of Manufacturing Processes
14.303-73	Developing and Using Typical Manufacturing Processes
14.308-74	Unified System for Production Tooling, Rules for Choosing Means of Mechanization and Automation for Processes of Transportation of Packed Piece Loads
14.310-73	Rules for Organizing Development of Production Equipment
14.311-75	Rules for Developing Manufacturing Processes
14.316-75	Unified System of Production Tooling, Rules for Development of Grouped Technological Processes
14.317-75	Rules for Development Process of Inspection
14.318-83	Types of Process Inspection
14.320-81	Unified System of Production Tooling, Kinds of Assemblies
14.322-83	Rating Materials, Basic Revisions
14.401-73	Rules for Organizing Mechanization and Automation in Developing Engineering and Technical Tasks and Management Tasks
14.402-83	Automated System of Technological Preparation for Production, Composition, and Order of Development
14.403-73	Unified System of Technical Tooling, Rules for Selection of the Object of Automation
14.404-73	Unified System of Technical Tooling, Rules for Determining the Level of Automation of Problem Solving in Technical Tooling
14.408-74	Automated System of Technological Preparation for Production
14.410-74	Rules of Choosing Technical Means of Collecting, Transmitting, and Processing Information for Tooling

14.412-79	Requirements for Program Provision of Information Searching Systems for Technological Purposes
14.413-80	Data Bank for Technological Purposes, General Requirements
14.414-77	Automated Data Retrieval System for Production Processes, Rules for Development
14.416-83	Organization of Automated Technical Planning

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