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Cost Implications of Soviet Ship Design and Construction Practices

A Research Paper

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Information available as of 1 July 1981 has been used in the preparation of this report.

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Cost Implications of Soviet Ship Design and Construction Practices

Overview

Soviet surface combatants delivered between 1960 and 1980 have in general been smaller, faster, and less costly to procure in dollar terms than their US counterparts.[1] These characteristics resulted from design decisions which traditionally produced ships that:

- Were manpower intensive rather than automated—separate radars and fire control were used for most weapon systems.
- Were constructed of commercial-quality equipment and materials—pumps, valves, and communications equipment in many cases identical to those on commercial vessels.[2]
- Introduced newer technology only when necessary—gas turbine propulsion to replace large, low-pressure steam plants

Soviet construction practices complement these design decisions and contribute further to lower unit costs:

- Eighty of the 81 major surface combatants constructed between 1960 and 1980 were built in only four shipyards.
- Designs were frozen early and production runs were long and stable

Soviet practices are changing, however, as can be seen in ships under construction, which will enter the Soviet fleet in 1981 or later. The new classes are larger and more capable than previous classes. Soviet designers are adopting more modern designs and technology—for example, nuclear propulsion powers the recently commissioned Kirov-class cruiser, and weapon systems are being placed inside the hull rather than topside

[1] The procurement costs in this report are expressed in dollars and are not actual Soviet expenditures. They are estimates that represent what it would cost to produce a ship of the Soviet design in a US shipyard using US factors of production, materials, and equipment. The duration of construction programs and the quality of materials and onboard equipment reflect Soviet practices, as derived from intelligence sources. This report examines Soviet units from 1,000 to 10,000 tons full-load displacement and mentions larger units only for certain comparisons.

[2] Commercial quality does not imply inferiority in material or equipment. Such material, however, would usually not meet US military specifications and consequently costs less

These design trends will increase the dollar estimates of the basic ship procurement cost of Soviet major surface combatants in the future and will lessen the Soviets' cost advantages relative to the United States. We estimate that the average basic ship cost per ton of major surface combatants delivered in the 1980-84 period will reach $15,900—up 16 percent from 1975-79. (If we include the estimated cost of the nuclear cruiser Kirov, the average cost per ton will exceed $21,000.

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Cost Implications of Soviet Ship Design and Construction Practices

Introduction

This report describes the ship design decisions and construction practices that determined the procurement cost of Soviet surface combatants during the 1960-80 period. It concentrates on the cost of the basic ship: hull, propulsion system, electric plant, installation of communications and control equipment, auxiliary systems, outfitting and furnishing, and installation of armaments. The procurement costs of armaments, associated fire-control systems, and radars are estimated using separate methodologies and are excluded from all ship costs presented in this report

To assess the interplay of these design decisions and construction practices and their effect on cost, we developed a generalized cost model of Soviet major surface combatants. This model combines intelligence judgments, the analytic expertise of a leading US naval architectural firm, and the cost and manufacturing experience of a US shipyard. The costing model is described briefly in the appendix.

Design Decisions

The primacy of the war-fighting mission of Soviet surface combatants and other operational requirements have led Soviet ship designers to make a series of interrelated decisions that determine the character and capabilities of Soviet frigates, destroyers, and cruisers. The same decisions have kept the increase in average cost per ton of basic ship to less than 30 percent over the past 20 years

To reach design objectives, the Soviets have applied standards different from those of the United States in such areas as accessibility, range, habitability, onboard repair capability, resupply at sea, and damage control. Soviet surface combatants can be characterized as war expendable. They are designed to strike fast and engage in short, intensive combat. Each ship carries many different kinds of weapons, and the ammunition on board would not support lengthy combat operations. Consequently, when compared with their US counterparts (see table 1), Soviet ships are:

- More manpower intensive and crowded.
- Smaller and simpler.
- Less capable of prolonged periods of sea-keeping.
- More powerful and faster

Ship classes now nearing the end of their production runs have designs that date back to the 1960s. New classes entering the Soviet Navy or nearing sea trials indicate that in the early 1970s the Soviets began to change their design philosophy. They now are constructing larger surface combatants, some of which are equipped with more complex naval weapon systems, automation, nuclear power, and other advances.[1] As a result, the cost of current and future generations of Soviet ships probably will increase more rapidly than in the past.

Major Technological Changes

In Soviet naval ship design, change is slow and evolutionary. Rather than pursuing technological leaps that push the state of the art and risk failure, Soviet designers tend to stretch an existing design to the limit of its capability. When this limit is reached, technological change appears in the next system and tend to be as modest and risk free as possible

The Kresta I and Kresta II classes of guided missile cruiser (CG), for example, were produced at the same shipyard for 15 years without major change in the basic ship. There were major differences in weapon systems, but otherwise the main differences between

[1] Design of the nuclear cruiser Kirov, which was laid down in 1973, started even earlier—by the mid-1960s

Table 1

Selected Characteristics of Soviet and US Surface Combatants [a]

	Full-Load Displacement (*Long Tons*)	Shaft Horsepower (*SHP*)	Maximum Speed (*Knots*)
Soviet Major Surface Combatants and Small Frigates			
Frigate [b]	1,200-3,800	31,000-73,000	30-32
Destroyer	3,550-4,825	72,000-95,000	36-38
Cruiser	5,500-9,725	92,000-146,000	33-36
US Major Surface Combatants			
Frigate			
Destroyer			
Cruiser			

[a] This table includes only ships commissioned between 1 January 1960 and 31 December 1980. Different operational requirements have led the Soviets to design ships of the 1960s and 1970s with characteristics different from those of US ships. The new generation of ships, which will begin entering the Soviet Navy in 1981, will be as large as or larger than comparable US ships and will reflect changes in requirements as perceived by the Soviets.
[b] Frigates less than 2,500 long tons are included in the table, although they are now classified as minor surface combatants.

the Kresta I (a four-ship class) and Kresta II (a 10-ship class) were an extended and modified bow and a helicopter pad raised by one deck.

Over the past 20 years, three major technological changes have occurred in Soviet major surface combatants: gas turbine propulsion, nuclear propulsion, and the ability to handle aircraft. After the initial introduction, however, each new capability seems to have evolved slowly

Gas Turbine Propulsion. In the late 1950s, Soviet frigates and destroyers were powered by large, low-pressure steam power plants. Rather than attempting to make steam plants smaller and more efficient, the Soviets turned to the gas turbine engine, a technology developed by the aircraft industry

Gas turbines were first installed on small patrol craft (Poti PG [1]) and fast frigates (the Mirka FFL) in the early 1960s. In these original applications, turbines were used as boost engines in the direct-thrust mode in the same way as on aircraft. Large diesel engines provided cruise power. On subsequent minor surface combatants the gas turbine boost engines were connected through reduction gears to propellers, as they are today.

In 1963 the first major combatant completely powered by gas turbines, the Kashin-class destroyer (DDG), was commissioned (see figure 2). The Kashin has four engines that drive two shafts through reduction gears. With an estimated 95,000 shaft horsepower (SHP), the Kashin has more installed power than a comparable US destroyer of the same period [2] and has attained a trial speed of 38 knots. The Krivak I, a large frigate introduced in 1970, also has four gas turbines. The

[1] The Poti class PG is not studied here; it is mentioned only because it was one of the first to use gas turbine.

[2] The Charles F. Adams-class destroyer, commissioned from 1960 through 1964

Figure 2. Kashin-class guided-missile destroyer (S)

design of the Krivak I's propulsion system showed considerable improvement, however: it had two small turbines for economical cruising and two large ones for high-speed dashes.

During the 1950s and 1960s, the Soviets were satisfied with their steam power plant for cruiser-sized ships, and they did not install gas turbines in cruisers until the early 1970s, when the Kara was introduced. The Kara is equipped with two small cruise turbines and four large boost turbines, has a total of 146,000 SHP, and has attained trial speeds of about 35 knots. We believe that most of the new classes of Soviet surface combatants that enter service in and after 1981 will use gas turbine propulsion.

Nuclear Propulsion. The Kirov, a large cruiser completed in 1980 at the Baltic Shipyard in Leningrad, embodies the latest technological advance for surface combatants—nuclear propulsion (see figure 3). The Kirov is the only nuclear-powered surface combatant in the Soviet Navy. The Soviets, however, have had substantial experience with nuclear propulsion in icebreakers and submarines—the Lenin, an icebreaker constructed in 1959, was the world's first nuclear-powered surface vessel.

Two more powerful follow-on icebreakers, the Arktika and the Sibir, were completed in 1974 and 1975, respectively. These were built at the Baltic Shipyard, as was the Kirov, which was built on the same construction way as the Sibir. The Kirov may be powered by the same type of reactor plant used in the Sibir. However, other features of the Kirov's propulsion system—oil-fired superheat and geared steam turbines—make its design distinctly different from that of the Sibir, which uses a turboelectric drive.

Aircraft-Carrying Ships. The significance of airpower at sea has been recognized by the Soviets for some time. Their first entrant in the carrier class was the antisubmarine warfare (ASW) cruiser Moskva, which became operational in 1968 (see figure 4). This ship carries 16 ASW helicopters and is arranged as a cruiser forward and a helicopter carrier aft. The second stage in carrier development was the Kiev, which the Soviets refer to as a heavy, aviation-carrying cruiser. The Kiev has an angled flight deck [redacted] and it is estimated to carry 15 vertical takeoff and landing (VTOL) aircraft and 16 helicopters. An aircraft carrier equipped to handle conventional aircraft is probably under development for delivery in the late 1980s.

This history illustrates the general Soviet mode of development. The degree of technological change in aircraft-carrying ships was minimal at first—simply an extension of the cruiser design—and subsequent developments have been evolutionary

Automation

After analyzing detailed published information on the Kapitan Smirnov, a modern commercial roll-on/roll-off cargo ship built in the USSR, we know that the Soviets can design and construct:

- Fully automated controls for gas turbine engines.
- Remote controls for electric plants and for air compressors, pumps, and other ship systems.
- Computerized ship control and navigation systems.

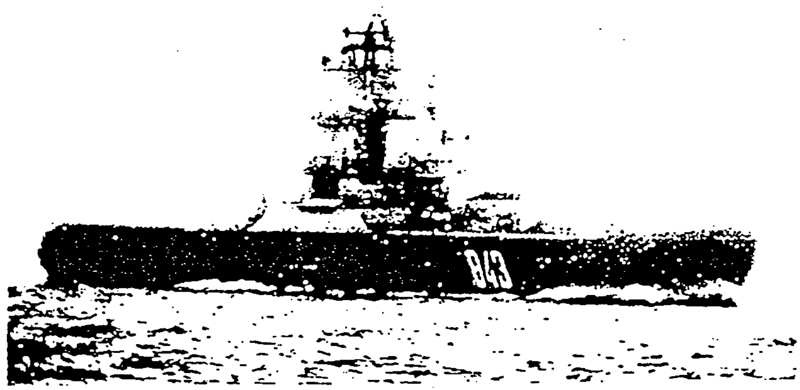
There is no indication, however, that these costly and complex systems are installed on most Soviet surface combatants (the Kiev and the Kirov cruisers may have some of them). Control of the engine from the bridge is probably the extent of the automation on most combatants. It appears that Soviet designers continue to rely on manually operated rather than on automated systems in surface ships, as they do in weapon and electronics systems

Armaments and Electronics

Although armaments and electronics are not included in the cost analysis presented in this report, the characteristics of these systems merit explanation because of their impact on basic ship design practices

In general, the weapon and electronics systems installed on Soviet ships are redundant and relatively simple. We currently estimate that each gun battery and missile system has a separate fire-control system and that some of them have backup optical fire-control systems. Unlike the US practice of using a single launcher for various types of missiles, Soviet ships usually have at least two launchers for each missile system, each launcher having its separate magazine and fire-control system. Weapon systems usually are mounted on deck with their magazines nearby —a practice that significantly increases the vulnerability of the ship but allows the Soviets to place an impressive number of weapon systems on a relatively small ship.

Figure 4. Moskva-class ASW cruiser



Over the past 20 years, some of the weapon systems installed on Soviet major combatants were developed originally for the ground forces (see table 2). In fact, some systems apparently designed for the ground forces were deployed initially aboard ship—possibly for testing.

Construction Practices

In the study of procurement costs, it is sometimes difficult to isolate the impact of design changes from the impact of production methods and traditions observed in Soviet shipyards. For example, the following discussion of an early design freeze could have been placed in the section on design decisions (pages 1-6). It is placed under construction practices because of its pervasive effect on procurement practices, labor force stability, and production rate.

Early Design Freeze

We believe that the design of a Soviet combatant usually is frozen before the lead ship has been completed—possibly even before the keel is laid. Subsequent ships of the class are apparently identical. This simplifies considerably the procurement of materials, components, machinery, armament, and electronics. If a serious design problem arises early in the construction of a new class, the Soviets are more likely to drop the class and proceed to an entirely new design than to try salvaging the faulty design through massive modifications. For example, the Soviets apparently were dissatisfied with the design of the Kynda-class cruiser and produced only four units.* They then proceeded to the larger, more capable Kresta I class, which places more emphasis on antiaircraft capabilities.

Rather than make numerous changes in a ship class while it is in production, the Soviets tend to accumulate desirable changes and introduce them all at once. The ship in which all of the changes are made is often sufficiently different from its predecessors to be considered a new class, even though the basic ship characteristics have changed little. For example, between Kresta I and Kresta II significant changes were made in the armament and radar, which enhance the ship's performance in the ASW role, but the basic ship was changed only slightly. Likewise, the Krivak I and

* The Moskva helicopter-carrying cruiser also had design problems and consequently only two ships were built

Table 2

Soviet Weapon Systems Used by Both Naval and Ground Forces

Ground Force Designation	Naval Designation
Identical systems (missiles)	
SSC-1-B	SSN-3-B
SA-2	SA-N-2
SA-3	SA-N-1
SA-8	SA-N-4
SA-10	SA-NX-6
SA-11	SA-NX-7
Possibly related systems (guns)	
57-mm AA gun mod S-60	57-mm 70-cal dual-purpose gun
100-mm tank gun (T-54/55)	100-mm dual-purpose gun

Krivak II classes differ mainly in their gun armament. Production of Krivak I continued at separate yards all during the production run of Krivak II

Another way of making changes is to return ships to the yard after the class production run has been completed and retrofit them as a separate program. The Kashin-class DDG, produced at Nikolayev and Zhdanov Shipyards from 1963 through 1972, is an example of this practice. In 1971, as production of the class was nearing an end, some of the ships completed earlier began to return to Zhdanov and Nikolayev for modification. Five ships were included in this program and are designated the Modified Kashin class.[7] Among the more conspicuous modifications were:

- Lengthening and redesigning the stern to accommodate a variable-depth sonar.
- Raising the helicopter platform one deck.
- Extending and widening two levels of the bridge structure.
- Adding four SS-N-2c launchers, four six-barreled gatling guns, and additional radars (see figure 5)

[7] The 20th ship of the original Kashin class, which was completed in 1973, was built from the keel up as a Modified Kashin, bringing the total Mod Kashin class to six ships

Construction Quality

In general, the construction specifications for Soviet major surface combatants can be characterized as equivalent to good US commercial or Coast Guard specifications but not to US Navy military specifications. Soviet naval specifications—although they are more demanding than those governing the construction of commercial ships—are a subset of the GOST[*] standards for merchant ship construction, rather than a comprehensive series of requirements as are the US military specifications. In some cases, such as cable and pipe hanging, local shipyard practice prevails. Furthermore, quality control and the accompanying documentation are roughly equivalent to those in the United States before 1970. In the final analysis, the basis of Soviet quality assurance is the warranty of the shipyard. As stated by one source, "... outside consumers [naval units] were not concerned with components but only with the performance of the end product."

The Soviets conserve scarce technical resources wherever possible. Commercial equipment and machinery are used on naval vessels when their use will not interfere with performance of the ship's mission. Navigation radars, communications equipment, pumps, motors, and electrical equipment are often identical to those observed on Soviet merchant ships.

As we have found in other types of Soviet military equipment, quality appears to be adequate—no better than needed to fulfill a basic function. Close tolerances, high-quality welds, and excellent finishes are found where they are essential. Where high quality is not important to ship performance, tolerances are loose, welds are rough, and finishes are poor by US standards

Yard Specialization and Production Duration

Soviet shipyards tend to build the same types of ships over prolonged periods. Of the 204 surface combatants displacing from 1,000 to 10,000 tons delivered between 1960 and 1980, 172 were constructed in only five

[*] Gosudarstvennyi Obshchesoyuzniy Standart, or State All-Union Standards

yards. More striking, 80 of 81 major surface combatants were built in four yards and among these, 50 of 51 cruisers and destroyers came from two yards.

Zhdanov Shipyard, for example, has built cruisers for more than 18 years and is now working on two new classes. All of the Kynda and Kresta cruisers were built at Zhdanov—18 ships over 18 years. In addition, some of the Kashin-class destroyers were built at Zhdanov, and part of the Kashin modification program was conducted there. This long-term production stability brings a yard many economic benefits. The logistics network can be firmly established, and procurement items that require a long leadtime can be ordered well in advance. A stable, well-trained labor force, fully familiar with the construction of large surface combatants as well as with Navy requirements, can be trained and retained. Shipyard workers building naval ships reportedly are paid 20 percent more than workers building commercial vessels, and consequently the yards that build naval ships tend to attract and retain the best workers.

Soviet surface combatant classes remain in production far longer than those of the United States, and this permits a long-term scheduling of naval ship construction that encourages stability at the yards. In the United States, large ships such as the Belknap-class cruiser, the Adams-class destroyer, or the Knox-class frigate have usually been built in at least three yards and delivered over a short period, usually two to five years. Table 3 lists the large Soviet classes and the delivery periods.

Table 3

Selected Soviet Surface Combatant Deliveries, 1960-80

Name and Class	Number Produced	Number of Yards	Delivery Period (Years)
Kresta I-II CG	14	1	12
Kara CG	7	1	9
Kashin DDG	19	2	11
Krivak I-II FFG	32 [a]	3	12
Petya I-II FFL	62	2	18
Mirka I-II FFL	18	1	5
Grisha FFL	42	3	14

[a] What probably are the final units of the Krivak class have not yet begun sea trials. The 21st Krivak I is fitting out at Kerch and the 11th Krivak II at Kaliningrad. They will probably be delivered in 1981.

Cost Implications

Through the 1970s, Soviet design philosophy and shipbuilding practices tended to make Soviet surface combatants less costly from a dollar standpoint than their Western counterparts. The cost of ships now under construction, however, is increasing as the Soviets expand their "blue-water" navy in numbers, size, and capability. This section discusses the main cost trends in Soviet shipbuilding over the last 20 years and explains the cost impact of Soviet design and construction practices .

Trends in Cost Per Ton

One of the most meaningful measures of cost growth in shipbuilding is the average basic ship cost per ton (expressed in constant dollars to remove the effect of inflation). This measure excludes the cost of weapons and electronics and reflects:
- Technology advances in equipment and material.
- Improvements or declines in productivity.
- Variations in ship sizes and capabilities.
- Institutional factors such as the number of yards producing a class and the size of the production run.

For these reasons, average cost per ton is the measure

During the same period the US Navy took delivery of 159 major surface combatants from 15 shipyards. Only three US yards produced more than 20 ships; the other 12 yards produced from two to 13 ships each.

The Spruance-class destroyer is the exception. It was built in a single yard designed for a modular, "production-line" construction process.

The model upon which CIA's cost estimates of Soviet major surface combatants are based includes an estimate of technological change over time, allows for the savings obtained by the use of commercial materials, equipment, and standards, and reflects the cost reduction obtained by the Soviet practice of producing a large number of identical ships in a small number of yards over an extended period of time. See appendix for further details.

used in this section to trace trends in the cost growth in Soviet surface combatants over the past two decades.

The average basic ship cost per ton of Soviet surface combatants has risen only about 27 percent over the past 20 years. The modest nature of this growth rate is caused by two factors: the mix of combatants constructed and the relatively unchanging design approaches followed by the Soviets, particularly for small frigates.

For large frigates, destroyers, and cruisers (from 3,000 to 13,000 tons full-load displacement), the cost per ton has increased almost 40 percent over the past 20 years (see table 4).[12] The greater-than-average increase reflects design changes and qualitative improvements in propulsion, habitability, and construction quality.

New classes of ships now on sea trials and others under construction are much larger than previous Soviet designs—as large as or larger than similar US classes. This represents a significant change in Soviet design philosophy, which must have occurred during the late 1960s and early-to-mid-1970s. The design choices which determined the characteristics of earlier classes may no longer apply to these new classes.

Although more than half of the ships built during the last two decades were small frigates (between 1,000 and 3,000 tons full-load displacement), they account for only 25 percent of the tonnage delivered. These frigates were relatively costly per ton during the early 1960s, partly because they were small[13] and partly because of their high-powered CODAG (combination of diesel and gas turbine) power plants. In the early 1960s the smaller ships cost 25 percent more per ton than large combatants. Over the 20-year period, however, their cost per ton increased only 9 percent (compared to the large ships' 40 percent), so that currently the cost per ton is about the same for both (see table 5).

[12] The 13,000-ton displacement ships will start being delivered during 1981-82.

[13] Because of economies of scale the basic ship cost per ton decreases as ship size increases.

Another significant reason why the cost per ton for small frigates has remained roughly constant is that only three classes totaling 122 ships have been built between 1960 and 1981.[14] The ship design, displacement, and propulsion systems have been virtually unchanged on all three classes. The same manufacturer produces the cruise engines for all 122 ships—80 ships use one type of diesel engine and 42 use another.[15] For high-speed boost power, gas turbines are used on all; however, the arrangement and combination of engines are different for each class.

Two new classes of small frigates are expected to enter service in the early-to-mid-1980s. About 15 of these new, more costly ships should be completed by 1984.

Size

Soviet ships delivered from 1960 through 1980 tend to be less expensive in dollar terms than their US counterparts because they are lighter and smaller, and shipbuilding costs are driven primarily by weight and volume. The Soviets have built tightly packed ships, which have a relatively high payload for the size of the ship. They place the armaments topside (with multiple relatively simple fire-control systems and redundant magazines), and they provide only poor habitability.

The "tight" Soviet ships of the 1960s and 1970s are the result of several design choices. The military decision to accept reduced safety and performance margins is shown in such characteristics as:

- Firemains sized to supply the largest single load (for example, fire fighting, nuclear washdown, or magazine flooding), rather than a maximum combined emergency load.
- Air conditioning only for essential compartments.
- Little redundancy in auxiliary equipment.
- Limited electric power output.

[14] Mirka class, 18 ships (1963-67); Petya class, 62 ships (1960-77); Grisha class, 42 ships (1967-81).

[15] The Mirka and Petya classes use the Russkiy Dizel (Russian Diesel) 60-D-3, a 16-cylinder opposed-piston engine, whereas the Grisha class uses the Russkiy Dizel M-507, a 42-cylinder 6-row radial engine. The latter engine is also manufactured in 7- and 8-row versions for patrol boats and hydrofoils.

Table 4

Tonnage and Estimated Cost of Major Surface Combatants [a]

Time Period	Number Delivered (Units)	Tonnage Delivered (Long Tons)	Average Displacement (Long Tons)	Total Cost (Million 1979 Dollars)	Average Cost (1979 Dollars Per Ton)
1960-64	14	68,950	4,900	802	11,600
1965-69	18	99,200	5,500	1,176	11,900
1970-74	21	119,675	5,700	1,503	12,600
1975-79	26	134,200	5,200 [b]	1,837	13,700
1980-84 [c]	25	181,500	7,300	2,892	15,900
1980-84 with Kirov	26	205,500	7,900	4,352	21,200

[a] Ships from 3,000 tons to 13,000 tons full-load displacement including large frigates, destroyers, and cruisers.
[b] The average displacement declined in the late 1970s because of the large number (19) of relatively small Krivak I and Krivak II frigates procured.
[c] These estimates for 1980-84 include the new classes of ships entering the Soviet fleet during the period but exclude the nuclear-powered cruiser Kirov.

Table 5

Tonnage and Estimated Cost of Small Frigates (1,000 to 3,000 tons full-load displacement)

Time Period	Number Delivered (Units)	Tonnage Delivered (Long Tons)	Average Displacement (Long Tons)	Total Cost (Million 1979 Dollars)	Average Cost (1979 Dollars Per Ton)
1960-64	26	30,420	1,170	441	14,500
1965-69	43	50,430	1,170	764	15,200
1970-74	27	32,040	1,190	482	15,000
1975-79	23	27,510	1,200	415	15,100
1980-84	18	30,600	1,700	483	15,800

Similar choices include:
- Minimum habitability provisions.
- Limited onboard maintenance facilities (and consequently a heavy reliance on depot or yard maintenance.)
- Low deck heights [redacted]
- Few dedicated storerooms.
- Little clearance around and poor accessibility to machinery and electronics equipment

Theoretically combining all of these design choices, a modern Soviet ship having the same payload weight, trial speed, endurance at 20 knots, crew complement, and installed shaft horsepower as a US ship would enclose only about 70 percent as much volume. In practice, this theoretical volume reduction is not fully realized; however, this approach is useful for capturing the effects of Soviet methods for cost-estimating purposes. Actual Soviet ships tend to have greater payloads, higher installed shaft horsepowers, and higher trial speeds than US ships with the same missions, although they are smaller (as shown in table 1 on page 2).

Table 6 — *Million 1979 Dollars*

Kresta II Program Cost Estimate

Following Soviet Practice					
Ships (10) delivered between 1969 and 1977 from one shipyard				=	930.5
Lead ship	1	x	114.2	=	114.2
Follow ships	9	x	90.7 [a]	=	816.3
Following US Practice					
Ships (10) delivered in 1969 and 1970 from four shipyards [b]				=	1,010.5
Lead ship (yard 1)	1	x	114.2	=	114.2
Follow ships (yard 1)	4	x	94.6	=	378.4
Follow ships (yard 2)	2	x	102.5	=	205.0
Follow ships (yard 3)	2	x	102.5	=	205.0
Follow ship (yard 4)	1	x	107.9	=	107.9

[a] Average cost.
[b] This approximates the pattern of production of the US Belknap-class cruisers. Only nine of these were built—five at one yard, two at another, and one each at two other yards. To simplify the comparison, we have shown the 10th hypothetical US-style Kresta as being built at Yard 3.

Commercial Quality

In addition to cost reductions because of size, the unit cost of a Soviet ship is further reduced by the choice of materials and equipment. Rather than meeting a plethora of military specifications for equipment and materials, the Soviets comply with far less stringent GOST or shipyard standards. The Soviet Navy does not require the extensive documentation and management control information that the US Navy does; it simply relies on the Soviet yards, which guarantee their product for a specified period of time after delivery.

Wherever possible, commercial-grade material is used in the construction of Soviet surface combatants and many components such as valves, fittings, and pumps are off the shelf rather than being specifically designed and produced for a military application. Some equipment is identical to that observed in commercial ships. For our cost estimates we calculate that the use of commercial-grade material, components, and equipment reduces the total material cost of Soviet ships by about 25 percent below that of the equivalent US ships.

Other Cost-Reduction Phenomena

In addition to minimizing size and using commercial quality hardware, the Soviets obtain significant cost savings from the duration of the production runs, the large numbers of ships in a class, and yard specialization. Yard specialization and long production runs permit the labor force in Soviet naval shipyards to be relatively stable and enable the workers to become thoroughly familiar with the construction of certain types of ships.

The estimated cost-reduction advantages of the Soviet ship construction practices can be seen from the example of the Kresta program shown in table 6. The upper portion shows our estimate of the cost of the Kresta II construction program, as carried out by the Soviets in a single shipyard. The lower portion shows the estimated cost if the Soviets had produced the 10 Kresta II cruisers in four different yards, as the United States produced its Belknap-class guided-missile cruisers

The incremental differences in the follow ships at the four yards reflect the parallel startup costs at each new yard. As can be seen, the theoretical savings obtained by building in one yard is about 8 percent. The actual savings would probably be higher, because the Soviet yard is geared to deliver about one ship per year (10 between 1969 and 1977). To produce 10 in two years and duplicate the US pattern would require expansion in plant and equipment, the use of additional yards, and the employment of new workers.

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Appendix

Major Surface Combatant Model

Under the sponsorship of the Joint CIA/DIA Military Costing Review Board, a major analytic effort was begun in 1977 to study the dollar cost of constructing Soviet major surface combatants in US shipyards. [redacted] The 1[illegible]-month effort resulted in a Soviet surface combatant cost-estimating model

The computer-based model is designed to estimate the dollar cost of replicating, in the United States, Soviet surface combatants in the range of 1,500 to 12,000 tons (full-load displacement).[illegible] The model does not estimate costs for armaments or electronics; these costs are estimated separately and added to the basic ship cost calculated by the model. The model cannot be used to estimate the costs of a US ship because it has been adjusted to incorporate ship design choices made by the Soviets. For example, such characteristics as deck heights, power-plant arrangements, water-main capacities, and electrical power output reflect Soviet practices and not those of the United States. To ensure that technological changes were accounted for, Soviet ship design characteristics were incorporated into three generalized designs reflecting the Soviet design choices of 1955, 1965, and 1975

Figure 6 shows the generalized 1975 Sovietized profile overlaid on the 1975 US Perry-class frigate (FFG-7). Both ships are designed for the same mission, and common performance characteristics dictated the final "Soviet" design.[illegible] The resulting "Sovietized" FFG-7 is shorter and narrower and has a shallower draft and lower overall profile than the US ship. The ships appear different for one fundamental reason — the United States makes one set of design decisions when building a surface combatant and the Soviets another

[illegible] The model can be used to estimate the costs of larger ships, but the results may be less accurate

[illegible] To ensure comparability, the generalized Soviet design has the same payload weight, trial speed, endurance at 20 knots, crew complement, and installed shaft horsepower as the US FFG-7

Figure 6

Comparison of US Perry-Class Frigate and Hypothetical "Sovietized" Version

Perry-Class FFG 7
Sovietized FFG 7