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Comments on Manufacturing Technology and Design Features of Selected Soviet Military Equipment

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CENTRAL INTELLIGENCE AGENCY
Directorate of Intelligence
April 1977

Comments on Manufacturing Technology and Design Features of Selected Soviet Military Equipment

Summary

The Intelligence Community recently had the opportunity to examine several Soviet weapon systems. In addition to detailed technical analyses of the weapons by many elements of the Intelligence Community, an analysis of the costs of producing the weapons in the US was sponsored by the Office of Strategic Research (OSR). An important by-product of that effort is a compilation of comments by US weapons manufacturers and military weapons experts who inspected the Soviet equipment. The comments are summarized in this paper.

The equipment included five major ground force weapons, two aircraft, and four surface-to-air missile (SAM) systems. Most had been manufactured since 1966, but the dates of initial production ranged from 1958 to 1970. All of the weapons which were examined are of types which are still widely used by the Soviet armed forces.

Two of the ground force weapons--the BMP infantry combat vehicle and the ZSU-23-4 antiaircraft gun--are

25X1A

25X1A [redacted] *Comments and queries regarding this publication are welcome. They may be directed to* [redacted] *of the Military-Economic Analysis Center, Office of Strategic Research, code 143, extension 7116, or gray 8319.*

representative of relatively complex land warfare systems which the Soviets have designed since the early sixties. The other ground force systems and the two aircraft are of earlier, less complex designs. The four SAMs which were examined showed a general continuity in design characteristics over time.

Since the weapons constitute only a small sample of the systems which the Soviets have designed and manufactured since the late fifties, the comments in this paper do not necessarily apply to Soviet military design and production practices in general. Several recurring themes, however, can be gleaned from the remarks:

-- The Soviet systems--unlike their US counterparts--typically were designed to perform only one or two primary functions.

-- The design and manufacturing techniques of each weapon apparently have remained basically unchanged for the entire production period.

-- Standardization of components was evident within a given system and among related systems.

-- Except for the BMP, the design of the weapons showed little concern for environmental effects.

-- Value engineering--minimizing production cost through hardware design--apparently was not emphasized.

Preface

The Intelligence Community recently examined several Soviet weapon systems--two aircraft, four surface-to-air missile systems, and five major items of ground force equipment. Most had been manufactured since 1966, but the dates of initial production ranged from 1958 to 1970.

Studies of the equipment were undertaken by the Intelligence Community to improve estimates of Soviet weapons performance. The Office of Strategic Research (OSR), in addition, viewed the opportunity for direct examination as a means to improve its estimates of procurement costs for these weapons. For this purpose a separate study of the available Soviet equipment, [redacted] was undertaken by OSR in conjunction with [redacted] and the Office of Weapons Intelligence, Directorate of Intelligence. 25X1A 25X1A 25X1A

A by-product of the cost analysis effort in [redacted] was a compilation of comments by US weapons manufacturers and military weapons experts who inspected the equipment. This paper summarizes their observations about Soviet manufacturing technology and weapons design. Although the comments are not intelligence assessments based on detailed analysis, they do provide important insights into the nature of the Soviet weapon systems which were examined. 25X1A

This paper does not present detailed cost analyses of the systems examined in [redacted] The cost analyses are still in progress and have been presented in other publications. 25X1A

Contents

Procedure and Scope

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[redacted] was initiated by the Military-Economic Analysis Center of the Office of Strategic Research to have weapons specialists examine Soviet military hardware firsthand. The specialists made cost estimates based on US manufacturing practices and commented on design and manufacturing philosophy and techniques. Many elements of the US intelligence and industrial communities assisted in the project.

Exploitation

Analysts from OSR, representatives from US weapons manufacturing companies, and weapons specialists from the US military were directly involved in examination of the hardware. Cost exploitation teams were formed to examine and analyze each piece of hardware. The exploitation was conducted at military installations, each item being examined for one or two days. The teams prepared cost estimates and comments on the design features as well as the technology that the Soviets used in the manufacture of the items. Of particular interest were characteristics reflecting standardization, quality control, and design concept.

The estimates and comments then were consolidated into intelligence handbooks for the use of analysts in OSR's Military-Economic Analysis Center. The information that follows was extracted from those handbooks.

Hardware Examined

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[redacted] involved the exploitation of two aircraft, four surface-to-air missile (SAM) systems, and five major items of ground force equipment. *(Photographs and descriptive notes are provided in the Annex.)* Most had been manufactured since 1966, and all are in current use.

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Soviet Military Hardware Examined

	Initial production/ deployment
Aircraft Systems	
Fishbed J export (MIG-21M) airframe	1968/1968
Avionics	
Spin Scan airborne intercept radar	Unknown/1963
Communications equipment	Unknown
Data link	Unknown
Gunsight	Unknown
R-13F-300 engine	1970/1970
Fitter A (SU-7) airframe	1957/1961
Land Arms	
BTR-60PB armored personnel carrier	1966/1966
BMP infantry combat vehicle	1967/1967
BRDM-2 amphibious reconnaissance vehicle	1966/1966
Sagger missiles	1969/1969
T-62 medium tank	1961/1962

[redacted]

	Initial production/ deployment
Land Arms (Continued)	
ZSU-23-4 antiaircraft gun	1965/1965
Surface-to-Air Missiles	
SA-2	1958/1959
Guideline missile (Mod 1)	1958/1959
SA-3	1960/1961
Goa missile (Mod 1)	1960/1961
Launcher	1960/1961
Guidance & control van	1960/1961
Low Blow target acquisition radar	1960/1961
SA-6	
Gainful missile seeker head	1969/1970
SA-7 Grail missile (Mod 0)	1966/1967

[redacted]

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The systems and components that were available for examination are listed in the table on pages 8 and 9. Some systems were intact, but subsystems on others were damaged or missing.

Except for the BMP infantry combat vehicle and the ZSU-23-4 antiaircraft gun, the systems in general do not have new design features, and most lack the more advanced features characteristic of Soviet land warfare systems designed since the early sixties.* The systems examined, therefore, do not represent current Soviet design technology. Rather, they reflect technology that went into the design of several currently deployed systems--and only indirectly reveal technology that will be incorporated in future systems.

Assessment of Design Features

25X1A The findings of the US weapons manufacturers and military weapons experts who participated in [redacted] 25X1A are summarized in this section (individual comments are compiled in the "Supporting Comments" section which follows). The features of Soviet weapons design and technology discussed below were identified by the participants as being common to most of the hardware examined. Not all were found, however, in the BMP and the ZSU-23-4--the newest of the Soviet weapons examined.

These comments should not be interpreted as reflections on the effectiveness of these weapon systems. They pertain only to differences between US and Soviet weapon design and manufacturing technology.

Simplicity of Design

The feature most frequently mentioned by project participants was design simplicity. This attitude or

* Design features and complexity of the BMP and ZSU-23-4 and other new Soviet land arms are discussed in detail in *Increased Complexity in Soviet Land Arms*, SR IR 75-15, September 1975 (Secret/No Foreign Dissem).

philosophy toward product design allows Soviet manufacturers to use standardized components, general purpose machines and conventional assembly operations in the production of weapons. Even the ZSU-23-4 was relatively simple in actual hardware, although it is considered innovative in the integration and optimization of components and complex in design concept. Only the BMP incorporated new components whose features represented significant changes in weapons design.

An important design criteria therefore seemed to be that the weapon could be produced with existing manufacturing methods. Existing manufacturing technology is more of a constraint on weapons design in the USSR than in the US.

Conservative Design

A dominant feature of most of the hardware examined was the conservative design, except for the BMP combat vehicle and the ZSU-23-4 gun system. The designers tended to use proven technology or standard components, and there was little apparent effort to strive for maximum system performance. For example, the MIG-21 and SU-7 airframes as well as the SA-3 launcher were judged to be bigger and heavier than required for their missions, and bigger and heavier than the US counterparts. This practice minimizes potential hardware stress problems but results in sacrifices to performance characteristics such as payload, range, and speed.

Limited Design Modification

The design reflected in nearly all the hardware examined has remained basically unchanged over long periods of time. The SA-2 and the SA-3 SAM systems perhaps are most illustrative of this. They were designed in the middle fifties and have been produced in several variants since the early sixties. The few design changes that were incorporated affected only specific systems components and did not reflect a general weapon system redesign. In the US, design modifications are made more often and are generally applied to all applicable components of a weapon system.

Standardization of Components and Subsystem Designs

Standardization of components within a given system and among related systems was evident. The SA-3 guidance and control van was a notable example. All relays and oil-filled capacitors were of three basic types; and standardized magnetics, vacuum tubes, and diode rectifier networks were used. Pneumatic actuators on the SA-2 surface-to-air missile and the AA-5 air-to-air missile appeared to be similar. Other parts such as clamps, brackets, and connectors appeared to be of common design and supply.

It was also evident that existing subsystem designs were used in new versions of weapon systems. For example, the ZSU-23-4 employs some subsystems used in earlier ground force antiaircraft artillery systems.

Little Attention to Cosmetics

High-quality or expensive manufacturing techniques generally were used only where absolutely necessary for system performance. By US standards finishes were rough and tolerances were loose on many Soviet weapons components and parts. This was especially true of MIG-21 and SU-7 airframes and engines and the SA-2 and SA-3 missiles.

Lagging Design Technology

Soviet design technology, for all systems except the BMP combat vehicle, was judged to lag that of the US. This apparently reflected a true technology gap in certain cases, while in others it probably resulted more from a preference for standardization and simplicity than from an inability to incorporate more advanced technology. The lag was particularly evident in electronics, and less obvious in mechanical systems. The evolutionary nature of design changes and a reluctance to introduce new production processes contribute to the technology lag.

Lagging Production Technology

The production techniques required to manufacture these weapons also are outdated by US standards. For

instance, the MIG-21 and SA-2 could have been produced without the use of any three-dimensional machining equipment. Also, with the exception of one or two parts, the MIG-21 engine could have been produced using manufacturing technology available in the early forties.

Labor-Intensive Manufacturing Methods

The production techniques used to fabricate these weapon systems reflects the fact that labor is cheaper relative to capital in the Soviet Union than in the US. Labor-intensive production techniques were used on all weapons. Perhaps the most obvious example was the use of the hand-stitched fabric cable on the wiring rather than plastic or heat-shrinkable cable commonly used in the US.

Reliability of Equipment and Ease of Maintenance

A detailed analysis of equipment reliability and ease of maintenance requires exploitation of greater depth than was possible in this project. A few comments were made by US weapons manufacturers regarding the reliability and ease of maintenance of Soviet equipment in the field based on their analysis of design features. Their comments are of interest and are reported on page 28, but are not sufficient for even tentative conclusions.

Supporting Comments

Quotations from the US experts who examined the Soviet equipment in [redacted] are detailed below. References in parenthesis identify the pieces of equipment. 25X1A

Simplicity of Design

"Adequate space was available for all the components of the system, making it easily producible. No unique manufacturing techniques were in evidence. Conventional techniques were utilized throughout the product. Consideration for cosmetic appeal appeared to be minimal." (SA-3 missile)

"Machining, chem-milling, and tapering for weight reduction are not apparent as on an F-4 or F-15. No use of titanium in place of alloy steel is made for purposes of weight reduction." (MIG-21 and SU-7)

"The machined components appear to be made from forgings or castings, with machining limited to such applications as critical surface mating (none for weight reduction). Soviet design does not require three-dimensional or sculptured machining. Alloy steel and aluminum (no titanium) is used for forgings, and aluminum and magnesium are used for casting." (MIG-21 and SU-7)

"Examination of the relative complexity and quality of the vehicle as compared to its US equivalent, the M60A1 [medium tank], indicates to us a lesser level of complexity as well as quality. Specifically, the vehicle lacks a range finder, and has suspension, powertrain, and fire control of simpler, less expensive design. We have estimated that this vehicle on a per pound basis represents a 20-percent less costly vehicle." (T-62)

"The above generalizations can be applied to the system as a whole; however, elements of the system (i.e., pressure vessels, actuators, etc.) reflected a well-developed specialized capability, possibly highly capitalized.... The modular makeup of the subject vehicle would permit the use of a large number of 'specialty manufacturers,' with only the final assembly of the sustainers being accomplished at an assembly facility. The point to be made here is that this vehicle permits more latitude along these lines than any other the writer is aware of." (SA-2 missile)

"...commitment to simple and straightforward execution of design to permit an equally straightforward execution in production." (SA-2 missile)

"The [SA-7] seeker is a functional, well-designed infrared seeker." (SA-7 missile)

"A generally unsophisticated approach to design in consideration of vibration and shock environment, Although no evident failures appeared. Although unsophisticated in approach to the problem, the use of shock mounts on the equipment main frame at all appeared as a surprise improvement to us. Studies by us of earlier vintage hardware had determined that all equipment was hard-mounted to the aircraft frame." (MIG-21 radar)

"Quality had been applied with more discretion/discernment than any other in the writer's experience. Where precision and care were required to assure function, they were readily apparent,

and where not required, little effort was expended. This would indicate a very mature and realistic approach to the application and control of quality requirements. An element that generally reflected a high level of quality, at least visually, were the welds. Machined parts best demonstrated the overall philosophy. Many were very crude by contemporary standards; however, they too reflected precision where required." (SA-2 missile)

"The chem-milling of skins [removal of metal by etching with an oblating chemical] shows rough surfaces, undercuts at edges, and sharp corners, none of which would pass US inspection. The Soviet integrally stiffened wing skins [a wing surface in which the outer skin and load-bearing supports--ribs--are cut out of one piece of metal] have ribs that are parallel to each other (do not follow percent lines*), are not high and thin, and are not tapered in thickness. Soviet riveting consists of nearly 100-percent driven-bucked rivets [a rivet that requires two operators for installation--one to hammer the rivet and another to hold the template that fastens it]; no blind fasteners [any one of a number of fasterners, such as screws, that only require one operator to install] are used. Extensive use of alloy steel fasteners is made rather than Monel, stainless, or titanium fasteners. There is little concern for the effects of dissimilar metal contact such as alloy steel to aluminum." (MIG 21 and SU-7)

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"Weight, volume, and technological advancement seem to be secondary to continued use of existing equipment." (MIG-21M communications)

** A percent line is the rate at which the gap between the ribs in an integrally stiffened aircraft wing widens or narrows from one edge of the wing to the other. To cut the metal from a wing and leave ribs that follow percent lines requires much more sophisticated machinery than does the cutting of metal to form parallel ribs.*

"The overall appearance of the hardware indicated that the major consideration in manufacturing was function, with little or no consideration for cosmetic appeal. Size and weight do not appear to be significant design criteria." (SA-3 missile)

"The Soviet design philosophy appears to be (1) a single purpose simplicity, (2) acceptance of a heavier airframe, and (3) shorter overall life in terms of environmental influences. Good finishes and close tolerances are not the general rule but are very good in the areas where they are really required. Corrosion protection such as exterior painting and plating are not equal to US standards." (MIG-21, SU-7)

"It was observed that the design agency had been very effective in [its] effort to achieve standardization in component selection and application. As we mentioned above, all relays were of three basic types and, in addition, oil-filled capacitors were of three general types of a similar degree of standardization among magnetics, vacuum tubes, and diode rectifier networks. In addition, all chassis, mechanical items, connector blocks, sheet metal, and hold-down hardware were standardized. Offsetting the advantages of standardization, however, we observed numerous instances wherein the standardization effort resulted in either a weight or volume penalty. This was especially true in certain of the chassis drawers where at times no more than 30 to 40 percent of the total volume was utilized. This was apparently the direct result of utilizing standard sheet metal enclosures, front panels, chassis dimensions, etc." (SA-3, command and control van)

"...it is a veritable fortress--heavy forgings and castings with all electronics encased in castings and further shielded by steel panels." (SA-3 launcher)

Limited Design Modification

"Extensive inspection of every solder joint was indicated by a color-coded varnish dot on each and every connection. No changes, re-works, or engineering improvements were indicated by the uniformity of the assembly and the untouched inspection marks." (MIG-21 radar)

"There were no obvious signs of post-manufactured change incorporation. We term such changes ECPs (Engineering Change Proposal) and tend to continually update the performance of equipment in the field through modification of circuitry. Such

modifications are usually obvious, since wire types are different, components are positioned in nonconforming places, and new wires are added outside of original wire bundles. The lack of such changes in this hardware indicates that the equipment design maturity is high, that upgrading of performance is done by substituting completely new suits of equipment, that changes are accomplished by rotating equipment back to the factory of origin for rather complete physical rework to incorporate functional changes, or some combination of these considerations." (MIG-21 radar)

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"The writer had the opportunity to review parts of an air-to-air vehicle from the same builder. In comparing the units, it has been apparent that a sincere attempt was made to use common hardware across a group of vehicles. The case in point revealed actuators (pneumatic cylinders) that were at least visually common to each vehicle. Additionally, hardware items (clamps, brackets, connectors) appeared to be common design and supply." (SA-2 and AA-5 missiles)

Little Attention to Cosmetics

"Adequate space was available for all the components of the system, making it easily producible. No unique manufacturing

techniques were in evidence. Conventional techniques were utilized throughout the product. Consideration for cosmetic appeal appeared to be minimal." (SA-3 missile)

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"The chem-milling of skins [removal of metal by etching with an oblating chemical] shows rough surfaces, undercuts at edges, and sharp corners, none of which would pass US inspection. The Soviet integrally stiffened wing skins [a wing surface in which the outer skin and load-bearing supports--ribs--are cut out of one piece of metal] have ribs that are parallel to each other (do not follow percent lines*), are not high and thin, and are not tapered in thickness. Soviet riveting consists of nearly 100-percent driven-bucked rivets [a rivet that requires two operators for installation--one to hammer the rivet and another to hold the template that fastens it]; no blind fasteners [any one of a number of fasteners, such as screws, that only require one operator to install] are used. Extensive use of alloy steel fasteners is made rather than Monel, stainless, or titanium fasteners. There is little concern for the effects of dissimilar metal contact such as alloy steel to aluminum." (MIG 21 and SU-7)

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"The entire hardware suit reflects impressive standards of workmanship, especially the handwork involved in assembly and wiring. The wiring is point-to-point: That is, each wire is routed and soldered into place individually. All solder joints are of good quality and consistent, and wires are evenly stripped and dressed. No loose wire strands (presume wire is stranded, but no check was possible) were evident. Hardware was not burred during installation." (MIG-21 radar)

"Machining operations (drill, punch, mill, etc.) are at an absolute minimum. Welds are not dressed; little or no attempt was made to remove burrs or flockings [residue from a coating applied to keep stamping tools clean] from stamping operations." (MIG-21 radar)

"The [gyro] spin and gimbal bearings appear to be of good quality with regard to the balls and ball grooves. Outside finishes are less than instrument bearing quality, however, giving the impression of a low-grade bearing. The poor coast-time characteristic of the gyro may be attributed to either an over-oiled condition or excessive preload." (SA-7 seeker head)

"A minimal use of anodize finish for corrosion protection; however, no sign of corrosion." (MIG-21 radar)

Lagging Design Technology

"This equipment, with a few minor exceptions, could have been designed by us in the 1950-1956 era and fabricated by us in the 1952-1967 era." (MIG-21 radar)

"Cost analysis study of a Soviet MIG-21M gunsight system reveals that the technology involved approximates that of similar US systems designed in the 1958-1960 period. A US manufacturer designed a gunsight in 1958 that looked very much like the MIG-21M system. It was manufactured in the 1960s." (MIG-21 gunsight)

Although the design is crude in some respects (note the external push rods to actuate the roll control, and the wire holding the booster fins in the folded position), it is quite functional in all respects." (SA-3 missile)

"...rugged, heavy, high-quality material and workmanship." (ZSU-23-4 guns, turret, and electronics)

"The examiners were particularly impressed by the BMP combat vehicle. It shows a degree of sophistication of armored vehicles which the Soviets were not expected to possess. The transmission and transfer case arrangement on the vehicle are excellent. Seals to assure pressurization are superior to those in the US, and it is equipped with automated CBR devices and a 73mm cannon loader that operates with an indexing ammunition basket which is unique and eliminates the need for a second gunner." (BMP)

"System capabilities concept was quite ambitious for the early 1960s. The technology represented is 15-20 years old relative to present state of the art." (ZSU-23-4 guns, turret, and electronics)

"The Soviet MIG-21M gunsight system was assembled with excellent workmanship, particularly in the electronics area. There was, for example, very careful tying of wire bundles, indicating that the labor content in the assembly of the equipment was high. The Soviets used better care in the details of construction than would have been used by the US in producing comparable equipment. Some of the wire connectors in the gunsight system were self-aligning and show advanced design techniques, considering the time of their manufacture." (MIG-21 gunsight)

"The equipment and technology are estimated to be approximately equivalent to our 1955-1960 vintage equipment." (MIG-21 communications)

"An analysis of the hardware available for observation showed the manufacturing technology to be comparable to that experienced [for US] missiles produced in the early 1950s. These missiles were an air/hydraulic system with vacuum tube type of electronics." (SA-3 missile)

"The technology used is not equivalent to the 1970 American technology. They have used mostly vacuum tube circuits with very little or no solid state circuitry. There were no observable printed circuit boards but rather mostly hard wire boards with discrete components. This system is probably equivalent to a late 1950 or early 1960 American system." (ZSU-23-3 radar)

"It is a vacuum tube type radar employing no solid state technology. Wiring is all by hand; no formed cables were in-

dicated. The entire unit is labor intensive, that is, hand labor was used to an excess in lieu of mechanical, automation, machine, or cost effective aid[s] in completing any operation. Cables are obviously assembled by hand--no crimping of wire connectors--and laced extensively (in fact it looks more like a good sewing stitch on the cable cover rather than a lacing job). Cable relief points are manually tied within the wire bundles, and each wire end is individually tied to prevent fraying. No use of teflon or heat-shrinkable plastic to protect these wire ends was observed. All of the above indicate a high use of manual labor rather than machines or other labor-saving devices." (MIG-21 radar)

"A large, flat rib-stiffened casting (appears die cast) on the antenna, of very thin section, is pushing, and may be beyond, our state of the art. From appearances, it is not acid dipped for thinning. It would be worthwhile studying this in more depth with respect to alloy type and method of fabrication." (MIG-21 radar)

"The general design period relative to US hardware would appear to be vintage 1942 through 1946. This equipment has a marked similarity to US World War II equipment in the selection and application of components. The command and control van is all vacuum tube, carbon resistor, with all chassis wiring cabled and laced. The only major departure from equipment of this approximate time frame (1942-1946) was the limited use of single-sided printed circuit boards. Such boards were relatively simple in circuit layout and density and were rigidly mounted and hard-wired to the internal chassis cable." (SA-3 command and control van and radar)

"Examination of the relative complexity and quality of the vehicle as compared to its US equivalent, the M60A1 [medium tank], indicates to us a lesser level of complexity as well as quality. Specifically, the vehicle lacks a range finder, and has suspension, powertrain, and fire control of simpler, less expensive design. We have estimated that this vehicle on a per pound basis represents a 20 percent less costly vehicle." (T-62)

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"This equipment, with a few minor exceptions, could have been designed by us in the 1950-1956 era and fabricated by us in the 1952-1967 era." (MIG-21 radar)

"The entire hardware suit reflects impressive standards of workmanship, especially the handwork involved in assembly and wiring. The wiring is point-to-point: that is, each wire is routed and soldered into place individually. All solder joints are of good quality and consistent, and wires are evenly stripped and dressed. No loose wire strands (presume wire is stranded, but no check was possible) were evident. Hardware was not burred during installation." (MIG-21 radar)

"Materials used appeared consistent with [those of the US] as did methods of fabrication and use of sheet metal tooling. There was a lack of newer style plastics, such as ABS (nylon), but other older types such as Micarta were in evidence." (MIG-21 radar)

"Electrical components appear to be quite similar to American manufactured components. Powdered iron or ferrite cup-cores like we use were in the ADF [automatic direction finder]." (MIG-21 electronics)

"The use of double insulated hook-up wire, with a plastic inner jacket (presumably for electrical protection) and fabric outer sheath (presumably for mechanical protection), ... would indicate a lack of plastic insulation capability either in terms of formulation or production capacity, since the technique used required more assembly time." (MIG-21 radar)

"Radar equipment, aside from antenna, employs subminiature vacuum tube discrete component point-to-point wiring technology--no semiconductors of pwbs." (ZSU-23-4 guns, turret, and electronics)

"Components, for the most part, had the appearance of being direct copies from ... major [US] suppliers. An interesting

observation was that many components were date stamped, with the latest observed date being 1967. Two items of component interest, in comparison to [US] hardware, are the lack of carbon resistors (the substitutes appear to be of ceramic composition), and, conversely, the lack of ceramic disc capacitors (most are tubular)." (MIG-21 radar)

"Adequate space was available for all the components of the system, making it easily producible. No unique manufacturing techniques were in evidence. Conventional techniques were utilized throughout the product. Consideration for cosmetic appeal appeared to be minimal." (SA-3 missile)

"...the minimal amount of special tooling and equipment required to produce. Assuming the next vehicle produced in this facility/facilities follows the same philosophy, it would be reasonable to project a very low cost and speedy re-implementation." (SA-2 missile)

"No unique or unknown manufacturing techniques were in evidence. Conventional machining and fabrication techniques appear to be utilized throughout the product." (SA-3 missile)

"Skills appeared to be commensurate with the requirement. Critical components, such as gyros, showed greater refinement in manufacturing techniques and skills than was evident for circuit board assemblies, machined surfaces, and exterior finishes." (SA-3 missile)

"The vehicle represents a Soviet commitment to engineering and tooling for production not normally to be expected. It also reflects a degree of craftmanship never before seen in Soviet produced equipment--a craftmanship which is not absolutely necessary, incidentally; e.g., surfaces finished which would not have to be put through the finishing production step." (BMP)

"The manufacturing techniques employed were approximately equivalent to those utilized in the US in the late 1950-early 1960 time frame. These techniques are adequate for this design but could not be utilized for today's sophisticated missile systems, due to cost, size, and weight." (SA-3 missile)

"The hardware available for observation did not appear to show any excessively difficult manufacturing requirements. The manufacturing technology employed appeared to be in line with the state of the art of the 1950s." (SA-3 missile)

"The packaging design of the SA-7 hardware requires the use of hand wiring techniques to a significant degree. It has been estimated that fully 95 percent of all component and/or circuit connections have been made by hand. With respect to printed circuitry, very little use has been made of this technology within the electronics boards, while this approach is implemented to only a slightly greater extent within the modules used within the control electronics. The overall electronic packaging is reminiscent of techniques utilized in early Mod 24 Redeye and Sidewinder (AIM-9B) hardware." (SA-7 missile)

"Manufacturing quality is good and the internal design is equivalent to US technology of the early 1960s." (SA-3 missile)

"Protection plating, coating, or painting is at an absolute minimum. Most individual chassis are raw aluminum. In areas where the equipment is painted (black), no preparation of the surface before painting is made. In a few areas, components were coated, but no general attempt was made to environmentally protect this equipment." (MIG-21 radar)

"The production methods/techniques employed require the sequential performance of several small increments (operations), each one generally requiring the use of a specific piece of universal equipment and frequently only hand or power tools. The associated skill levels required have been the semi-skilled grades; however, a high level of dexterity along with a general commitment to performance by the labor elements would be required to assure uniform product quality. There was virtually no evidence of the use of automated or high-rate production equipment in features where their use would be visually detectable; conversely, there was much evidence of manually controlled fabrication and assembly." (SA-2 missile)

"The construction of this seeker implies the existence of a facility which has a high-quality, accurate tooling specifically set up for this design. The basic cleanliness of the interior of the seeker head further implies a controlled area for assembly and testing where the standards for contamination are very high." (SA-7 seeker head)

"It was noted that electrical wire bundling was largely done manually, and that no micro-miniaturization was evident. Also, hydraulic piping and fittings used flared connectors, with little evidence of welded connections. It is concluded that in both these areas the Soviets are using techniques a decade or so old by US standards." (MIG-21 and SU-7)

"This equipment is simple, made to minimum standards in a plant with minimum sophistication and a large labor force." (MIG-21 radar)

"In conclusion, it is obvious that many more man-hours of labor are being expended on fabrication and assembly compared to US practices. There is little evidence that the Soviets are using automated fabrication techniques or advanced assembly methods." (MIG-21 and SU-7)

"The processes used to produce the chassis were old, established methods, and duplication would require no new or unusual equipment." (ZSU-23-4 chassis)

Labor-Intensive Manufacturing Methods

"Inspection was evidently detailed. Each electrical connection point, including some that were not wired, bore an inspection dye mark. In addition to an obvious visual inspection, this may also have included a chassis ring-out [check of circuits for continuity] of completed wiring. Each piece of hardware (nut, screw, etc.) also bore a dye mark that probably doubled as an antivibration operation such as our Glyptal applications of an earlier era." [Glyptal is a red liquid chemical that was applied to connectors. Upon contact with air it hardens and forms a seal that prevents the connections from vibrating apart.] (MIG-21 radar)

"The Soviet MIG-21M gunsight system was assembled with excellent workmanship, particularly in the electronics area. There was, for example, very careful tying of wire bundles, indicating that the labor content in the assembly of the equipment was high. The Soviets used better care in the details of construction than would have been used by the US in producing comparable equipment. Some of the wire connectors in the gunsight system were self-aligning and show advanced design techniques, considering the time of their manufacture." (MIG-21 gunsight)

"It is a vacuum tube type radar employing no solid state technology. Wiring is all by hand; no formed cables were indicated. The entire unit is labor intensive, that is, hand labor was used to an excess in lieu of mechanical, automation, machine, or cost effective aid[s] in completing any operation. Cables are obviously assembled by hand--no crimping of wire connectors--and laced extensively (in fact it looks more like a good sewing stitch on the cable cover rather than a lacing job). Cable relief points are manually tied within the wire

bundles, and each wire end is individually tied to prevent fraying. No use of teflon or heat-shrinkable plastic to protect these wire ends was observed. All of the above indicate a high use of manual labor rather than machines or other labor-saving devices." (MIG-21 radar)

"Extensive inspection of every solder joint was indicated by a color-coded varnish dot on each and every connection. No changes, re-works, or engineering improvements were indicated by the uniformity of the assembly and the untouched inspection marks." (MIG-21 radar)

"The entire hardware suit reflects impressive standards of workmanship, especially the hand work involved in assembly and wiring. The wiring is point-to-point: that is, each wire is routed and soldered into place individually. All solder joints are of good quality and consistent, and wires are evenly stripped and dressed. No loose wire strands (presume wire is stranded, but no check was possible) were evident. Hardware was not burred during installation." (MIG-21 radar)

"This equipment is simple, made to minimum standards in a plant with minimum sophistication and a large labor force." (MIG-21 radar)

"It was noted that electrical wire bundling was largely done manually, and that no micro-miniaturization was evident. Also, hydraulic piping and fittings used flared connectors, with little evidence of welded connections. It is concluded that in both these areas the Soviets are using techniques a decade or so old by US standards." (MIG-21 and SU-7)

"In conclusion, it is obvious that many more man-hours of labor are being expended on fabrication and assembly compared to US practices. There is little evidence that the Soviets are using automated fabrication techniques or advanced assembly methods." (MIG-21 and SU-7)

"The printed circuit assembly appeared to be hand soldered, with the body of the components held up off of the board during assembly." (MIG-21 communications)

"A lack of large plastic sleeving was apparent. The substitutes for this lack were hand-stitched protective covers on main cables, and the use of hand whipping [a tight binding that prevents cable unraveling] with string on cable and wire ends." (MIG-21 radar)

"The equipment is assembly labor intensive as opposed to utilizing technological advancement to reduce labor." (MIG-21 communications)

"The packaging design of the SA-7 hardware requires the use of hand wiring techniques to a significant degree. It has been estimated that fully 95 percent of all component and/or circuit connections have been made by hand. With respect to printed circuitry, very little use has been made of this technology within the electronics boards, while this approach is implemented to only a slightly greater extent within the modules used within the control electronics. The overall electronic packaging is reminiscent of techniques utilized in early Mod 24 Redeye and Sidewinder (AIM-9B) hardware." (SA-7 missile)

"Judging from the number of hand-soldered connections in the seeker head alone, a great deal of time and well-thought-out planning is required to assemble the hardware and avoid errors. (SA-7 seeker head)

Reliability of Equipment

"The team was impressed by the total number of control relays in the van electronics. By actual count, 489 relays are utilized, including snap-cover telephone type, hermetically sealed, and miniature. From the standpoint of reliability this would appear to be a potentially troublesome area." (SA-3 command and control van, radar)

"The team was equally amazed at the total number of adjustment potentiometers [these allow for screwdriver adjustment to vary the electrical current in a circuit] within the system. By actual count, 776 potentiometers are used throughout, and this again should have an additional effect upon system reliability." (SA-3 command and control van, radar)

"The forced-air rack cooling system would appear to be inadequate on several counts, namely, volume of air handled vs rack dissipation within the van enclosure. Even in the somewhat mild ... environment, the rack temperature appeared to be very high after a short period of operation." (SA-3 command and control van)

"The seeker apparently has low sensitivity in terms of state of the art in CW [continuous-wave] seekers. This may be deliberate in design strategy.... It is simpler and less expensive to produce target seekers with lower sensitivities, which in turn will not undergo as much receiver degradation when committed to field conditions. Thus, missiles are in a higher state of readiness and will require less field maintenance and readjustment." (SA-6 seeker)

"The mechanical characteristics of the resistors in use, however, are certainly less than desirable from a stress standpoint. When soldered in place, these devices can be fairly easily broken with only slight excessive handling of the hardware." (SA-7 missile)

Ease of Maintenance

"A corollary observation concerns field maintenance. Although estimates of field reliability are beyond the scope of our observations other than to note that this specific suit of hardware bore no signs of field repairs, the difficulty of field troubleshooting and repair is inherently obvious. As previously mentioned, the tightly packed, layered construction renders the replacement of parts (other than many of the tubes) difficult. Also, there are no service loops in the harness wiring [or] in the component leads. In terms of troubleshooting and fault isolation, it would appear that relatively highly skilled technicians are required. Presumably, there is some kind of special field test equipment to provide assistance in isolating faults to the black box level, and possibly some additional equipment to troubleshoot each black box at an intermediate or depot level. There are some test points on the front panels of the black boxes. But designed-in help* to the field users practically stops there. Wires are not individually marked [or] even basically color coded to indicate that they carry power, signals, etc. Chassis are minimally marked to indicate the specific component in the circuit that is mounted at that position. Although the pins are individually numbered on each terminal board, the boards themselves are not individually identified, and the individual terminals on large

** This includes any equipment aid to the field maintenance technician such as built-in terminals provided exclusively for checking circuit continuity, color-coded wiring for easy tracing, and identification marks on terminals. Later US equipment has computer program tapes which, when run through a piece of equipment, will isolate trouble spots.*

components are not identified. All of this means that highly experienced electronics technicians, working from a combination of schematics, wire tabs, and pictures or drawings, and using basic laboratory test equipment, are probably needed to service the hardware." (MIG-21 radar)

"The packaging concept used does render field changes difficult, at best. The hardware is densely packaged, built in layers, and all hard wired. There are no replaceable plug-in units that could be easily replaced in the field by improved versions, except at the complete black box level." (MIG-21 radar)

"These features indicate that the first equipment maintenance level is module replacement." (MIG-21 communications)

"The maintenance of the vehicle can be readily accomplished assuming the availability of a cadre of trained (not highly skilled) technicians. Most elements of the vehicle are easily replaced, adjusted, and in some cases, field repaired." (SA-2 missile)

"Each unit front panel provided numerous test points available to the technician. It would appear that all adjustment and trouble-shooting was performed by means of the numerous blown-fuse indicators and the several hundred test points as provided. The equipment does not feature a self-check capability or anything that would assist in rapid isolation and identification of faulty circuitry." (SA-3 command and control van)

"The graduation level electronic packaging design does not lend itself either physically or economically to any series rework, as any efforts to carry out repair work might well create more problems than they could solve." (SA-7 control package)

"Should an error or component failure occur, the gyro or seeker head is probably discarded because the design does not lend itself to rework or repair." (SA-7 seeker head)

Annex

Reference Guide to Soviet Military Hardware Examined

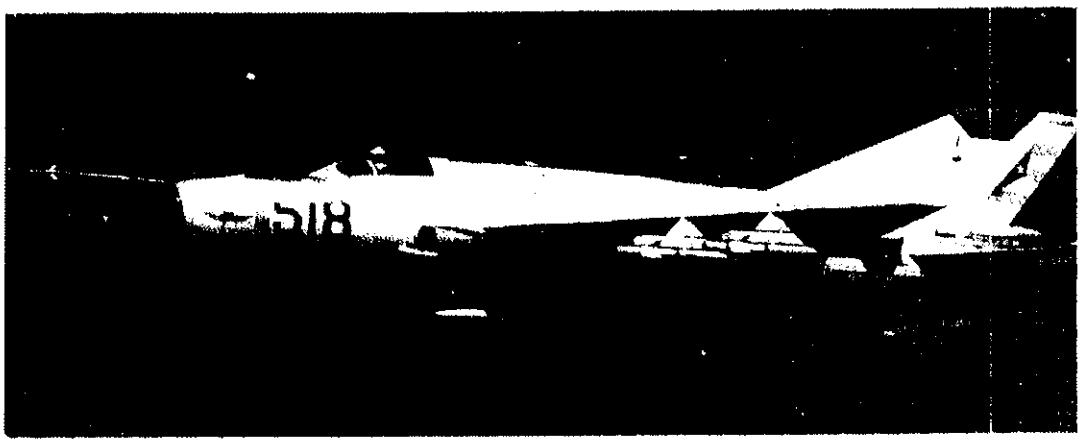
25X1A

The systems examined [redacted] were manufactured in either the late sixties or early seventies. Except for the BMP infantry combat vehicle and the ZSU-23-4 antiaircraft gun, however, their basic designs date back to the fifties and early sixties. Despite their apparent lack of sophistication, significant numbers of the systems are still used by Soviet and Soviet-supported military forces.

Aircraft Systems

MIG-21M Interceptor. The MIG-21M--an export version of the Soviet Fishbed J--is primarily an all-weather, medium-to-high-altitude interceptor with a secondary role of ground support. It is capable of Mach 2.0 flight. The MIG-21M is similar to the Fishbed J except that it is equipped with the older Spin Scan airborne intercept (AI) radar. The Fishbed J is equipped with the new Jay Bird AI radar, which gives it a better low-altitude intercept capability than the export version.

The MIG-21M represents a further development of the Fishbed series aircraft initially designed in 1952 by



the Mikoyan Design Bureau. The principal changes are an improved engine and weapons system. The aircraft is equipped with the R13-300 engine, which has a maximum engine thrust estimated at 64,500 newtons (14,500 pounds). This engine is a direct derivation of the R11F-300 afterburning turbojet engine used on some earlier Fishbed models. The most significant weapons changes made in the MIG-21M were the internal installation of a 23mm twin-barrel cannon and the addition of two more wing stations, which enables the aircraft to carry four, instead of two, air-to-air missiles.

There is some evidence that a later version of the Fishbed series--the Fishbed L export--has replaced the MIG-21M on the production line and is currently being fielded. However, the MIG-21M remains the mainstay of the non-Soviet Warsaw Pact air forces as well as the air forces of Egypt and Syria.

Fitter A Fighter. The SU-7 Fitter A is the first of three variants of a medium-weight, sweptwing, supersonic fighter designed in the early fifties by the

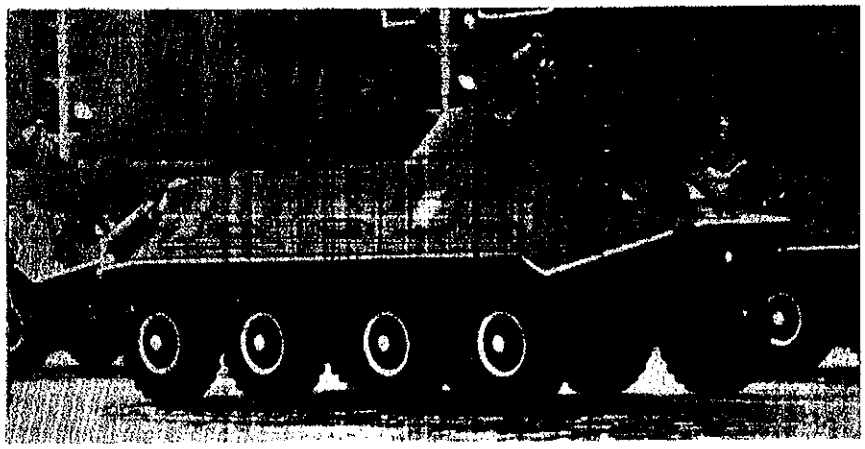
Sukhoy Design Bureau. Its primary mission is ground support and interdiction, but it also has limited capability as a clear-weather interceptor.

Series production of the Fitter A began in about 1957 and the fighter is estimated to have become operational in 1961. When fielded, it was equipped with an AL-7F turbojet engine. Its armament consisted

of one gun in each wing and a maximum payload of 2,000 kilograms (4,400 pounds). Fitter B and C aircraft--later variants of the Fitter produced in the late sixties and early seventies--have variable-geometry wings and were modified with an uprated engine, avionics, and increased payload. The Fitter A is being replaced by Fitter C and Flogger aircraft in Soviet Frontal Aviation, but there are still some 400 with Soviet units and about 100 with other Warsaw Pact air forces.

Land Arms

BTR-60PB Armored Personnel Carrier (APC). The BTR-60PB is an amphibious, eight-wheel-drive APC. It can carry 10 troops and is powered by twin gas-fueled engines.



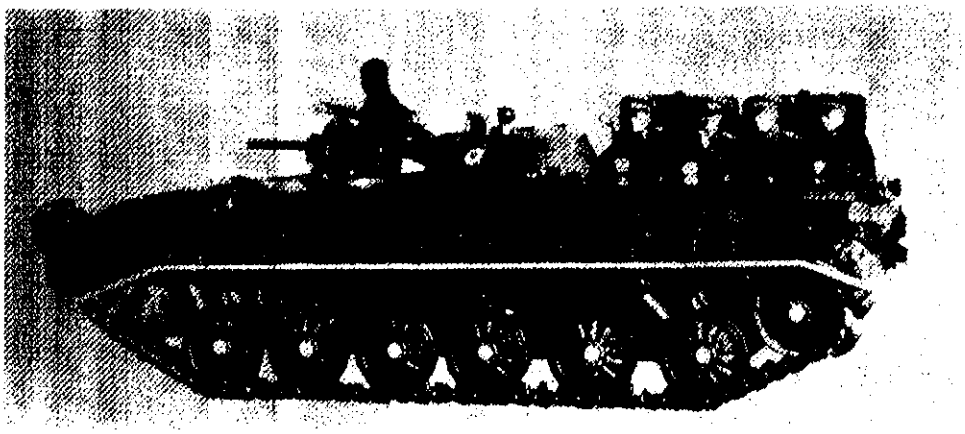
For amphibious operation, the vehicle uses a hydrojet propulsion system similar to that found on previous Soviet APCs.

The BTR-60PB has two machine guns in a small turret and is equipped with overhead armor. It entered production in 1966 and is based on the BTR-60P, an earlier version that lacked the turret and overhead armor. An intermediate version, the BTR-60PK, had overhead armor but no turret.

Currently both the BTR-60PB and the newer BMP are replacing older APCs in Soviet units. The Soviets

probably will continue to produce the BTR-60PB and field it throughout their forces in conjunction with the BMP.

BMP Combat Vehicle. The BMP tracked infantry combat vehicle entered service in 1967. Unlike most
25X1A systems examined [redacted] the BMP incorporates many advanced design features. The vehicle is similar to the earlier wheeled BTR-60 and tracked BTR-50 APCs in its ability to carry troops but is not limited to this role. It is armed with a 73mm smoothbore gun and the Sagger antitank guided missile; older

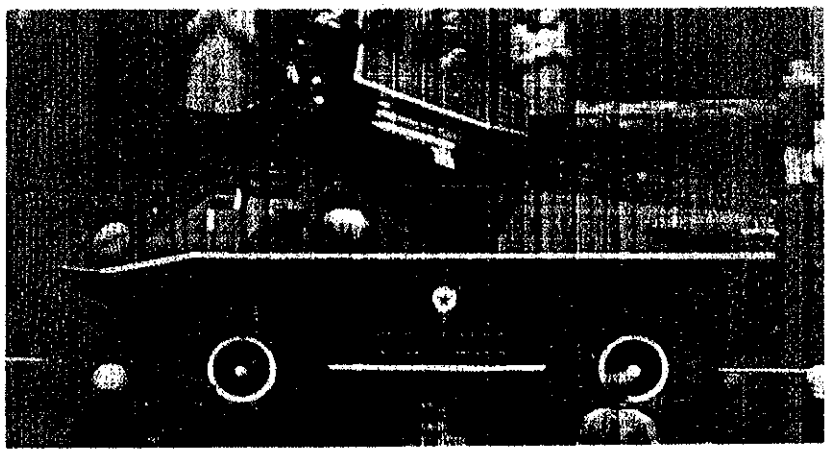


versions of this vehicle were armed only with heavy machine guns. In addition, the gun system on the BMP, unlike those of older Soviet armored vehicles, is fed by an automatic loader.

Other features of the BMP include a central ventilation system that provides protection for passengers and crew in a CBR environment; provision for venting the fumes from small arms that can be fired from inside the vehicle when it is closed; and improved armor, engine, and track. Only the BMP's amphibious propulsion system is less sophisticated than that of older vehicles. The vehicle moves by spinning its tracks, while some older vehicles have a hydrojet propulsion system.

BRDM-2 Reconnaissance Vehicle. The BRDM-2--an armored amphibious reconnaissance vehicle first fielded in 1966--is based on a BRDM vehicle produced in the early sixties. The BRDM-2 was initially armed with two machine guns mounted in a small turret, but in 1969 was modified to carry six Sagger antitank guided missiles

mounted on a retractable pylon. Like earlier versions of the BRDM-2, these modified vehicles have four-wheel drive, weigh about 6,800 kilograms (15,000 pounds) and have a top speed of around 95 kph (60 mph). They also have four auxiliary wheels for added mobility in poor terrain. The BRDM-2 has also been modified to serve as a transporter-erector-launcher (TEL) for the SA-9 surface-to-air missile.



T-62 Medium Tank. The T-62 medium tank, first fielded with Soviet tank and motorized rifle divisions in 1962, is a 36,000-kilogram (40-ton) vehicle armed with a 115mm smoothbore gun. The tank's gun is the only major improvement over the T-62's predecessor, the T-55, which was first produced in 1959. The T-62 uses the same engine, transmission, track and suspension system as the T-55.

The Soviets began fielding a new medium tank with their ground force units in the early seventies. This tank--the T-72--incorporates significant improvements over the T-62, and has been replacing older T-54 and T-55 tanks in Soviet tank and motorized rifle divisions. Nevertheless, it appears that the T-62 will remain in the active inventory for some time.

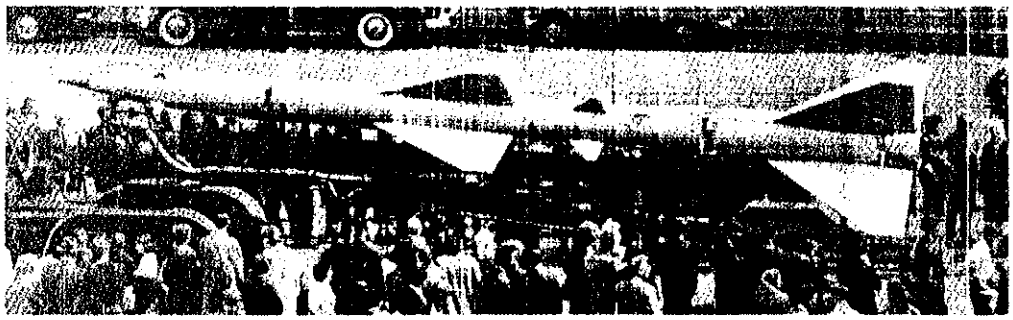
ZSU-23-4 Antiaircraft Gun. The ZSU-23-4 is a tracked tactical antiaircraft system for defense of combat units against low-flying aircraft and helicopters. The weapon was first produced in 1965. The most significant advan-

tage of this gun system over older weapons is the addition of an acquisition and tracking radar and a computerized fire control system. The fire control system has an analog computer that automatically aims the four 23mm gun barrels and an indicator that enables the system to distinguish between a moving target and background clutter.

Four ZSU-23-4s are in use in each Soviet tank and motorized rifle regiment. These weapons, together with the SA-9 SAM system, are replacing the older ZSU-57-2 self-propelled air defense guns in tank regiments and the towed light antiaircraft guns in motorized rifle units.

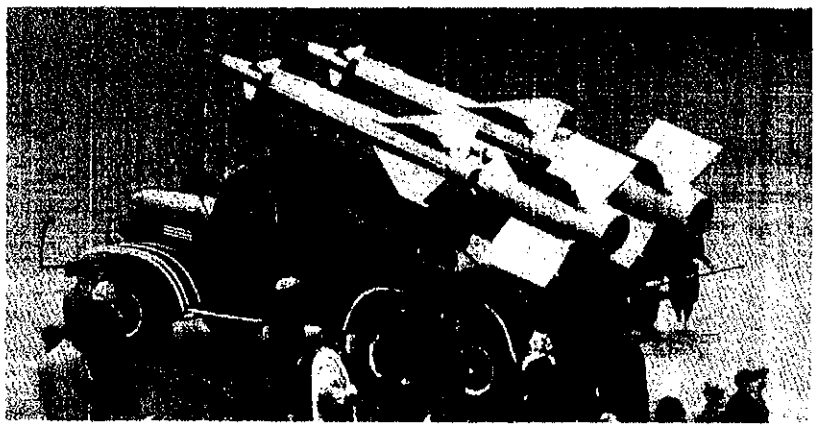
Surface to Air Missiles

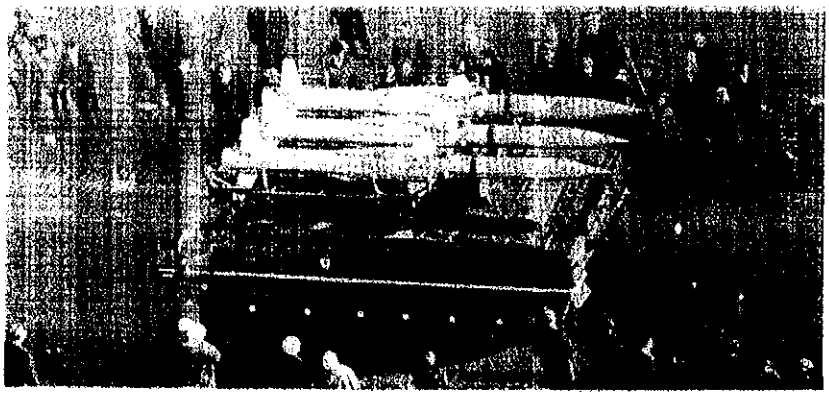
SA-2 Mod 1. The SA-2 is a command-guided SAM system designed to provide defense against aircraft flying at medium and high altitudes. The original version of this weapon entered the Soviet inventory in 1958. A modified version--the SA-2 Mod 1--was fielded in 1959 with an



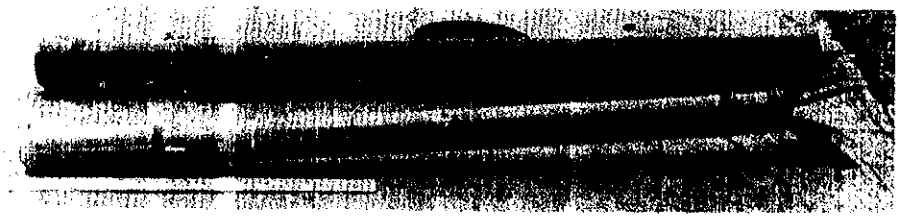
improved fire control radar, the Fan Song B. Since 1959, modifications have been made to improve the SA-2's low-altitude intercept and electronic counter-countermeasures capabilities. Although the SA-2 system is old and is gradually being phased out and replaced by newer systems, it is still widely used by Soviet strategic and tactical air defense forces.

SA-3 Mod 1. The SA-3 is a command-guided, transportable SAM system designed to provide point and barrier defense against aircraft flying at low altitudes.





SA-6



SA-7 missile and launch tube

SA-7 missile in launch tube with firing mechanism and battery attached

The system is primarily used to defend fixed targets. It was initially given to Soviet units in 1961. Modifications to the SA-3 have improved the low-altitude intercept and refire* capabilities of the system.

SA-6. The SA-6 is a mobile, short-range SAM system intended to provide Soviet field forces with defense against high-performance aircraft at low and medium altitudes. A prototype of this weapon was first seen in the 1967 Moscow parade, but it was not fielded until 1970. The system consists of three missiles on a TEL and associated acquisition and fire control radars mounted on separate tracked vehicles.

SA-7. The SA-7 is a man-portable, shoulder-launched, infrared guided SAM system developed for tactical defense against subsonic fixed-wing and rotary-wing aircraft flying at low altitudes. The original version of this weapon entered the Soviet inventory in 1967. It is similar to the US Redeye. A later version--the SA-7 Mod 1--was first observed with Soviet forces in 1972. This version has improved range and altitude capabilities.

*The Soviets are currently replacing the two-rail SA-3 launcher at some sites with a newer four-rail launcher. This doubles the number of ready missiles for firing from 8 to 16.

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