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Soviet Artillery Precision-Guided Munitions: A Conventional Weapons Initiative

A Technical Intelligence Report

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A Technical Intelligence Report

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Soviet Artillery Precision-Guided Munitions: A Conventional Weapons Initiative

Key Judgments

Information available as of 28 February 1986 was used in this report.

The Soviets have developed cannon-launched guided projectiles for their 122-millimeter and 152-millimeter artillery systems. Fielding probably began as early as 1983. The projectiles use laser semiactive homing guidance, which provides high first-round hit probability at ranges out to about 16 kilometers. We believe that there are both shaped-charge and high-explosive fragmentation warheads for each caliber of weapon

The Soviets embarked on their cannon-launched guided projectile development program in the early 1970s, about the same time or possibly earlier than the US Army's Copperhead program. By 1979 the Soviet program had been improved and accelerated by the adoption of guidance techniques and component desigr [redacted] The major benefits provided [redacted] were the techniques for design and manufacture of sensitive guidance components capable of withstanding the severe acceleration experienced by cannon-launched projectiles.

We believe that the artillery precision-guided munitions (PGMs) will greatly enhance Soviet artillery capabilities by providing force commanders with more effective fire support. Shaped-charge warhead PGMs are designed for use against armored targets, specifically tanks, while high-explosive fragmentation warhead PGMs are for use against high-value soft targets. We believe that the Soviet artillery PGMs will:

- Be employed predominantly with divisional self-propelled artillery weapons.
- Be effective against the antitank guided missile (ATGM) nests that NATO envisions employing against Soviet mechanized forces.
- Provide logistic benefits by increasing artillery tube life and by decreasing ammunition resupply requirements

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Introduction

The historical role of field artillery has varied little with time despite technological advances in war materiel. Large volumes of fire typically are concentrated on a parcel of land over a short time to suppress enemy forces. Because of the requirement for large amounts of ammunition, area type fire inherently imposes logistic burdens. Artillery also lacks sufficient accuracy to be effective against tanks and other hard targets. An army equipped with an accurate artillery-fired precision guided munition (PGM)—one that does not impose additional tactical and technical burdens on the artillery crew or on the artillery observer—will possess an effective force multiplier. PGMs permit artillery to threaten hard targets and could produce direct logistic benefits. High accuracy and effectiveness could reduce the number of shells expended per target and also extend the life of artillery tubes. As a result, there has been considerable motivation for the United States and the USSR to develop an artillery-fired PGM. Figure 1 illustrates the essential elements of operation of a laser semi-active homing type artillery PGM

The US Copperhead Program

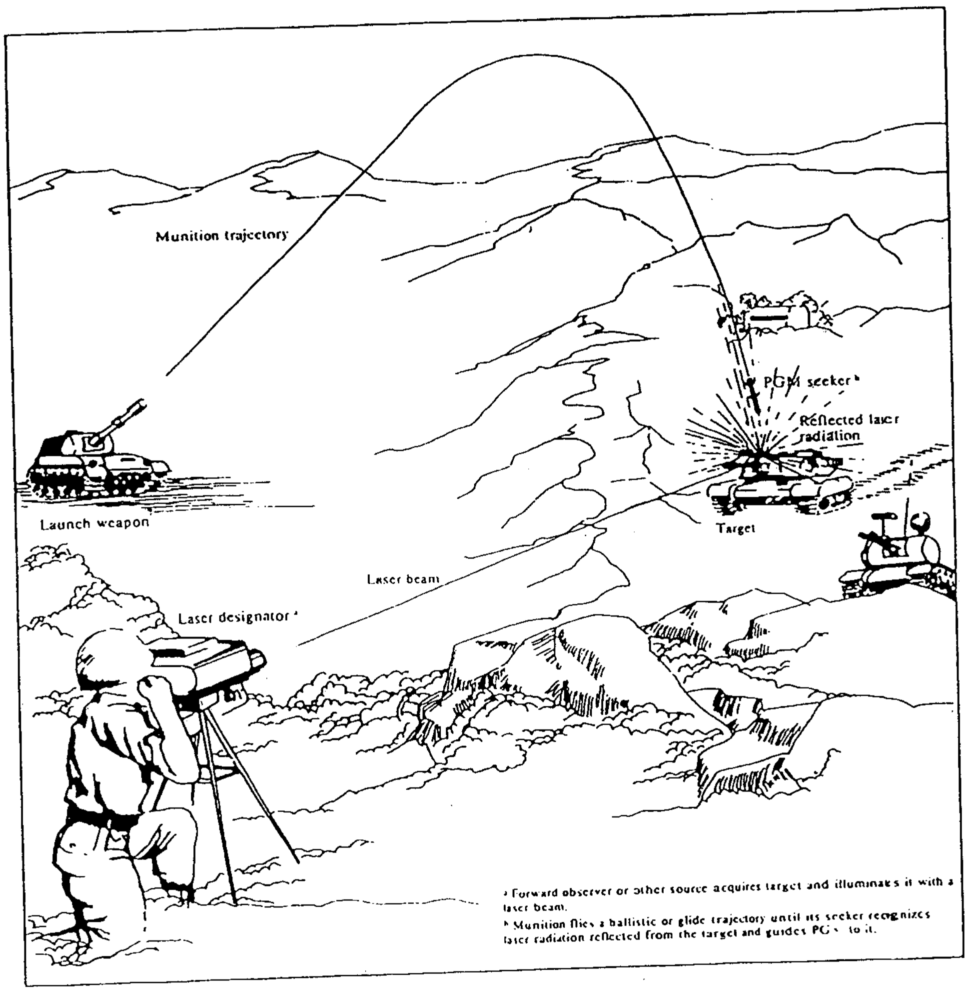
The US Army, overwhelmingly outnumbered by Warsaw Pact armored vehicles—particularly tanks—initiated its efforts to develop an artillery-fired PGM in the early 1970s. Building on earlier US Department of Defense PGM research, the Army embarked on a program to develop a cannon-launched guided projectile (the original program was known by the acronym CLGP) for use with 155-millimeter howitzers. In 1975 the Martin Marietta Corporation initiated engineering development of the CLGP, now called Copperhead. In 1979 Copperhead became the first artillery PGM approved in the United States, and production began in 1980. During the development cycle and afterward, a great amount of media coverage was devoted to Copperhead, often exposing considerable detail of its design, engineering, and operation

The Copperhead projectile is what is known as a wooden round.[1] It is stored and transported in the same way as other 155-mm projectiles and is compatible with all US and NATO 155-mm howitzers. Although the technologies employed in the Copperhead projectile are mature and not particularly sophisticated, the packaging of components—miniaturization and hardening against shock—is a significant engineering achievement. All components, including the internally stowed wings and control fins, are constrained to fit within the 155-mm diameter of the shell envelope. At launch, the projectile is subjected to the severe (9,000-g) launch acceleration force and to a high-pressure, hot-gas environment. Appendix A provides a detailed description of the operational sequences involved in aiming and launching a Copperhead projectile and guiding it to target

The Copperhead projectile consists of three sections—guidance, warhead, and stabilization and control (see figure 2). The rear two sections consist of straightforward technology and engineering. The forward section, however, is more complex; it consists of the seeker and the electronics packages. Hardening the seeker package, specifically the gyroscope, to survive launch forces was the major technical problem encountered in the Copperhead development program. The solution, a strap-down optics system using an optically coupled gyroscope, was a major innovation. A detailed discussion of the Copperhead hardening method is presented in appendix B

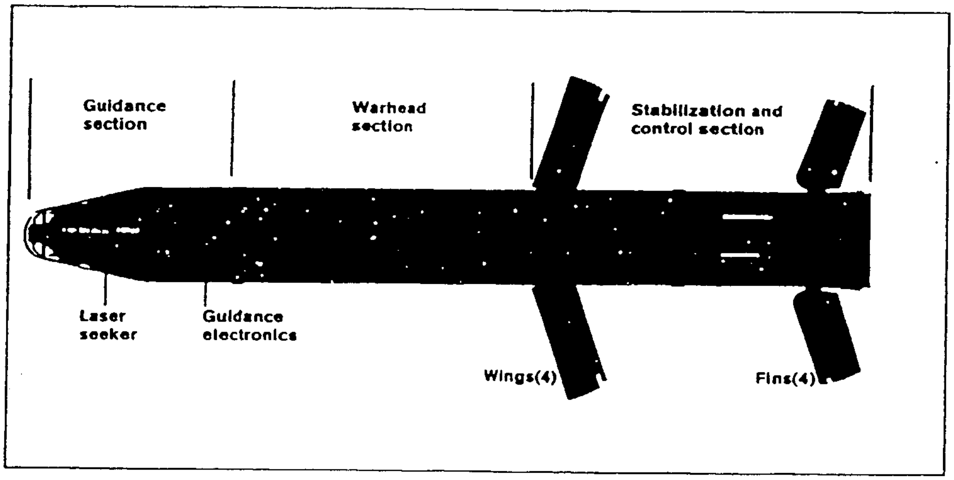
[1] A wooden round is a munition that can be fired as delivered from the factory. It requires no maintenance, testing, or additional parts in order to be fired

Figure 1
Laser Semiactive Homing Guidance Concept



[a] Forward observer or other source acquires target and illuminates it with a laser beam.
[b] Munition flies a ballistic or glide trajectory until its seeker recognizes laser radiation reflected from the target and guides PGM to it.

Figure 2
Sectionalized Diagram of Copperhead Projectile



The laser designator employed with Copperhead may be mounted on a number of different platforms—a vehicle, a tripod, or an aircraft, helicopter, or remotely piloted vehicle. US Army designators are all designed to be used interchangeably with different PGMs. They employ neodymium-doped yttrium-aluminum-garnet (Nd:YAG) lasers operating at 1.06 micron wavelength, with a pulse repetition frequency (PRF) between 10 and 20 pulses per second. The fundamental guidance concept of Copperhead is based on the projectile's receipt of reflected laser energy. The pulse sequence of the reflected beam must match a specific code structure that is preset before launch on both the designator and the projectile. Any other signals received by the projectile are rejected. Currently, the code can be selected from more than 400 available, permitting multiple simultaneous Copperhead firings on a battlefield without mutual interference. The multiplicity of coded signals also provides a degree of protection against electronic countermeasure

The Soviet Program

The running debate in the US press on the merits of the Copperhead program undoubtedly stimulated Soviet interest. For instance, Dr. William J. Perry, the Under Secretary of Defense for Research and Engineering in the late 1970s, was quoted in *US News and*

World Report as saying, "The Copperhead artillery shell, when it comes into service in 1981, will have an impact exceeding that of radar in World War II." During the 1975 to 1980 time frame, numerous articles appeared in Soviet journals, revealing their knowledge and interest in Copperhead. Appendix C is a translation of an article from a 1975 issue of the Soviet journal *Tekhnika i Vooruzheniya*. The article illustrates the Soviets' detailed understanding of Copperhead early in its development

Evidence for the Program

We believe that the Soviets independently embarked on their own guided artillery projectile development program in the early 1970s, about the same time or possibly earlier than the US Army program. We also believe the Soviet program successfully developed a Copperhead-like PGM—which we refer to as Copperheadskyy—

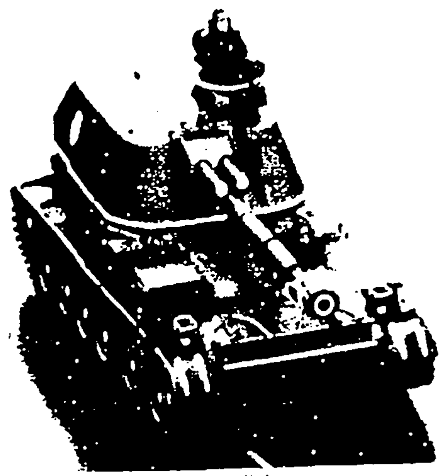


Figure 3. Soviet 152-mm self-propelled howitzer, 2S3

Deployment Evidence

Therefore, we believe a Copperhead-like projectile has been developed and fielded in limited numbers with 152-mm artillery. A likely candidate for projectile deployment is the 152-mm self-propelled howitzer, 2S3 (see figure 3)

Table 1

[redacted]

Training Evidence [redacted] describe other dry- and live-fire artillery exercises which, while not conclusive, strongly suggest the use of actual or notional artillery PGM. [redacted] support our assessment that artillery-fired PGMs are deployed and give some insight into Soviet tactics for their use

[redacted]

[redacted]

Possible R&D Organizations Supporting the Program
To identify likely milestones in the development and deployment cycles of the Soviet Copperheadskyy munition, we reviewed applicable Soviet laser-related activities, other laser-guided munition programs, and possible artillery PGM production activitie:

Laser-Related Activities [redacted] convince us that Soviet designers and producers were heavily engaged with laser devices and laser-related PGMs by the middle-to-late 1970s. Although Copperheadskyy actually may not use one of those known laser devices as its laser designator system, it quite likely uses a very similar onc

[redacted]

[1] US Copperhead projectiles, for example, currently cost about $35,000 eacl

Table 2
Soviet Laser-Guided Munitions

[redacted]

the design of tank gun-launched antitank guided missiles (ATGMs). One of the ATGMs, designated AT-8 by NATO, is fired by T-64B and T-80 tanks. Tank gun-launched ATGMs have greater than normal ATGM velocity and probably are supersonic. They probably experience considerable launch acceleration forces when fired, although less than is experienced by Copperhead in an artillery tube. Clearly, the design bureau is experienced in designing fragile munition systems that can survive launch into high-velocity flight.

[redacted]

[redacted]

Copperheadskyy Characteristics

We believe that there are two Copperheadskyy variants—122 mm and 152 mm. Each variant has either an HE-fragmentation or HEAT warhead. [redacted] confirms PGM munitions have been deployed with 152-mm artillery. We also believe 122-mm PGM munitions have been deployed [redacted] We do know, however, that there was an ongoing developmental program for the 122-mm howitzer, and [redacted] It is highly unlikely, based on technology and manufacturing restraints, that warheads are interchangeable for a given variant caliber. Instead, we assess that each variant/warhead combination exists as a fully assembled projectile

We have little data on Copperheadskyy's technical characteristics. Nonetheless, the direct acquisition of US Copperhead technology for use in the Soviet development program and the parallels between the US and USSR programs (both had to contend with the same technical and physical restraints) provide substantial basis for assessing some Copperheadskyy characteristics. It probably resembles Copperhead quite closely in configuration and applied technologies. The Copperhead projectile, however, has only a HEAT warhead, while the Soviet guided munitions also have an HE-fragmentation warhead. The Soviet munition, therefore, probably is intended to attack a broader range of targets

Because the Soviet PGM is generically similar to Copperhead and the Soviets were able to use US design information in its development, it probably has the same performance envelope as its US cousin.

Figure
US and Soviet Artillery Precision Guided Munitions Development Programs, 1971-85

Consid-ering range capability first, we noted that the Copper-head range capability is approximately equal to the maximum range of the weapon using conventional ammunition. Applying the same criteria, we assess range capabilities of the Soviet 152-mm and 122-mm projectiles to be 3 to 17 km and 3 to 15 km, respectively. Additionally, it is highly probable that the Soviet round employs wings like Copperhead; therefore, possible range extensions of 25 percent, using the wings for gliding, are assessed for each variant. On the basis of demonstrated Soviet capabilities with a wide variety of laser-guided weapons and especially the probable benefit from borrowed Cop-perhead technology, we feel confident that the accuracy of both Soviet variants is equivalent to that of Copperhead; in other word

.[3] Larger ceps, however, could be

[3] Circular error probable is defined as the radius of a circle, centered on the target, within which 50 percent of the munitions can be expected to impac

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tolerated for HE-fragmentation warheads than for HEAT warheads, because the relatively large radius of damage from HE-fragmentation warheads would make them effective against soft targets even when the miss distance is many feet. On the other hand, extreme precision is required of HEAT rounds in order to be effective against armor.

If Copperheadskyy HE-fragmentation warheads use similar technology to standard Soviet HE-fragmentation shells of the same caliber—152-mm model OF-540 and 122-mm model OF-462—we would expect the damage radius of the former to be degraded, because some space normally used by the warhead must be sacrificed to carry guidance and control, sensors, fins, and wings on the guided-artillery projectiles. The Soviets, however, probably have optimized fragmentation warhead design for the munitions to improve lethality. They recently increased the effectiveness of some other artillery warheads by using a more energetic explosive filler, aluminized RDX. We also know from [redacted] that they are knowledgeable of and capable of developing controlled-fragmentation warheads. By employing aluminized RDX in a controlled-fragmentation warhead, we believe that an optimized warhead, having nearly the same lethal radius as the older standard HE-fragmentation rounds of the same caliber, is achievable and, with the PGM's much better accuracy, provides a much more effective munition against soft targets.

Using their mid-to-late-1970s technology, the Soviets developed shaped-charge warheads that achieved penetrations of as much as six cone diameters (CD).[c] Assuming that the same level of technology is employed in Copperheadskyy shaped-charge warheads and using the standard estimate for charge diameter as 90 percent of shell diameter, we computed their expected penetration capabilities. Further, presuming similarity in projectile design, the Soviet warheads would, like Copperhead, be degraded [redacted] because of the sensor's presence in front of the warhead. Accordingly, we calculate penetration capabilities of at least 660 mm and 530 mm of rolled homogeneous armor (RHA) for the 152-mm and 122-mm projectiles, respectively. Using newer Western technology and employing thinner projectile wall thicknesses, however, penetrations of as much as 800 mm and 630 mm, respectively, are possible (see table 3).

Roles and Missions of Copperheadskyy

The purpose in developing a shaped-charge warhead for an artillery-guided munition is to attack armor—specifically tanks. This probably is the role for Copperheadskyy munitions with shaped-charge warheads. Shaped-charge warheads combine good penetrability, great precision, and inherent high angle of attack, the combination of which offers a large kill probability against tanks and other armored vehicle targets. The complementary Copperheadskyy munitions with HE-fragmentation warheads provide a highly accurate threat against personnel and other soft targets. To be cost effective, such a munition must be used to attack soft targets of significant military value. Copperheadskyy with HE-fragmentation warheads, therefore, probably will be used against targets such as personnel, ATGM nests, radars, command posts, and SAM fire units. Copperheadskyy munitions with both kinds of warheads should provide effective fire support for a Soviet commander and would benefit both offensive and defensive operations.

Although the Soviet guided munitions could be fired by any 122-mm or 152-mm howitzer, we believe self-propelled howitzers will be the primary users. Self-propelled artillery has the inherent shortcoming of limited onboard-ammunition capacity. A PGM's great effectiveness per projectile, however, should partially compensate for this shortcoming. These guided munitions appear ideally suited for use by Soviet divisional self-propelled howitzers, which must be responsive and furnish direct fire support to the maneuver force. Considerable evidence exists associating Copperheadskyy with the 2S3 self-propelled

[c] CD is a measure of total penetration into rolled homogeneous armor divided by the diameter of the shaped charge. CD is used as a means of normalizing penetration data to permit comparison of warheads of different diameters and to provide a measure of warhead quality and level of applied technology.

Table 3
Copperheadskyy Characteristics

	122-mm Variant	152-mm Variant
Range	3 to 15 km	3 to 17 km
Accuracy	[redacted]	[redacted]
Type warheads	HE-fragmentation, HEAT	HE-fragmentation, HEAT
Penetration (HEAT)	530-mm RHA	660-mm RHA
Lethality (HE-fragmentation)	Approximately equal to OF-462 [a]	Approximately equal to OF-540 [a]

[a] OF-462 and OF-540 are the older standard HE-fragmentation shells for 122-mm and 152-mm howitzers, respectively.

howitzer [redacted], we believe that the 2S1—the Soviet maneuver regimental commander's direct support artillery weapon—is another prime candidate for Copperheadskyy employment (see figure 5)

We believe, however, that not all self-propelled artillery weapons will carry Copperheadskyy munitions. Partially influenced by economic considerations, the munitions probably will be deployed both in limited quantities and to select units. The Soviets will have to establish adequate rules of engagement to ensure effective servicing of targets by the blend of Copperheadskyy and conventional artillery munitions. Also, to effectively use the new munitions, a proficient laser designation capability will have to be established

The mission of Copperheadskyy, though, as we see it, is primarily one of enhancing the effectiveness of divisional self-propelled weapons to provide fire support to the maneuver force. Copperheadskyy may serve as the guardian of Soviet armored columns and formation:

The Impact of Copperheadskyy

Divisional self-propelled howitzers supplied with Copperheadskyy munitions will provide a maneuver force commander with accompanying support artillery that is highly mobile, responsive, accurate, and lethal and that can also carry adequate amounts of onboard ammunition. Because the majority of self-propelled howitzers in the Soviet Ground Forces inventory are deployed in the Western Theater of Operations, we believe that their greatest use will be there

Although probably intended for use against both armor and high-value soft targets, we believe Copperheadskyy's prime target will be the ATGM nests that NATO plans to employ against Soviet mechanized forces. ATGM nests have high military value because of the damage they can inflict on tanks and armored vehicles. It is highly likely that Copperheadskyy HE-fragmentation variants will be able to effectively neutralize these nests, because of the high-munition kill probability. Consequently, we believe

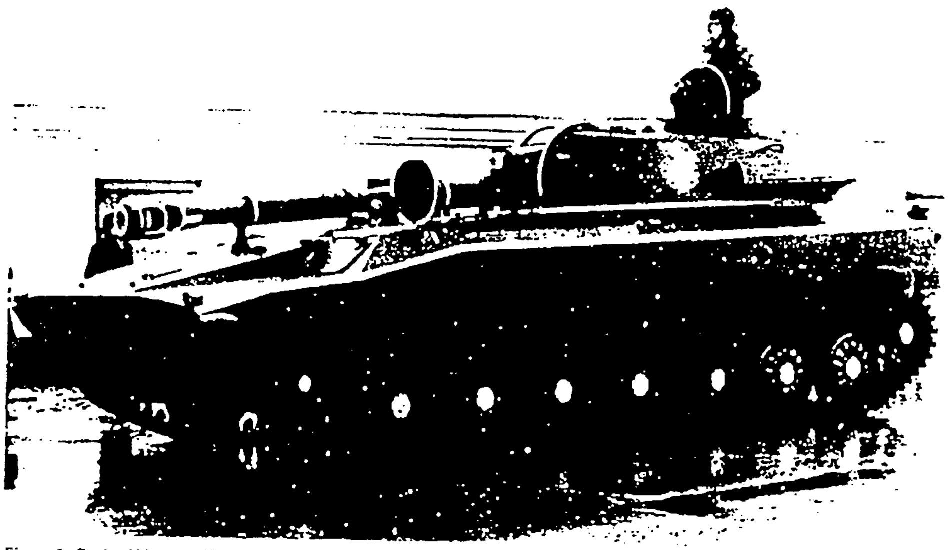


Figure 5. Soviet 122-mm self-propelled howitzer, 2S

the main impact of Copperheadskyy munitions is offensive, especially in countering NATO's planned defensive strategy. This employment of Copperheadskyy is another factor to enhance the Soviet maneuver force's ability to maintain the rapid advance rates advocated in their offensive warfare doctrine.

The great effectiveness per projectile provided by Copperheadskyy will also yield logistic benefits to the Soviets. Obvious benefits are that fewer rounds will be required per target killed, lessening the requirement for ammunition and decreasing artillery tube wear. A less obvious benefit, as previously discussed, is the enhancement of self-propelled artillery effectiveness.

Appendix A

Copperhead System Operation

The following operational description is extracted from an article "Copperhead—The Evolution of a Revolutionary Weapon," which appeared in *Journal of Defense Research*, vol. 13, no. 2, summer 1981, pages 192 and 19-

The sequence of events from launch through terminal flight is shown in figure 6. Prior to firing, the laser code, flight time event sequencer, and guidance mode (ballistic or glide) are set, using the code and time switches. Flightpath angles can be preset to the desired glide slope for optimum performance. The round is then loaded and rammed, the proper powder charge added, breech closed, azimuth and elevation set, and primer added. Copperhead is then ready for the fire command

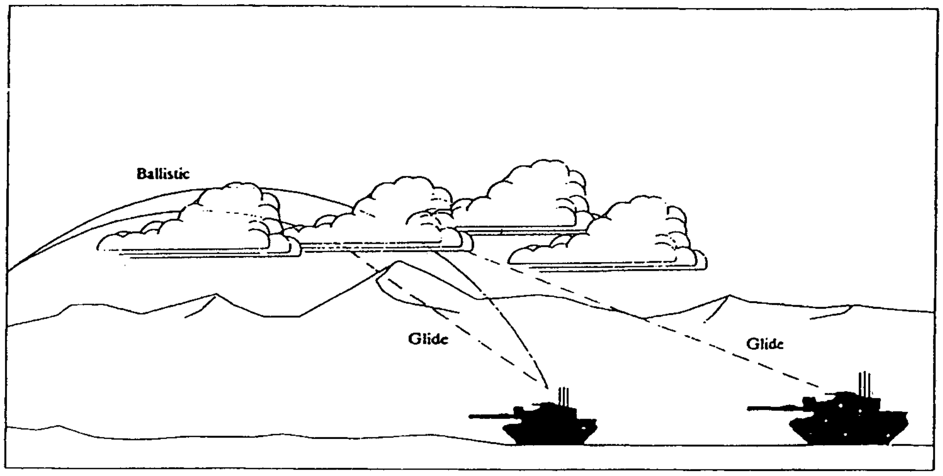
At launch, the slip obturator seals the propelling gases, and the round moves up the tube with spin limited by the obturator to 30 revolutions per second. Acceleration activates the + 11 volt battery and starts the timing sequence. At 800 g, the warhead safe-and-arm device activates to partially arm the round. At barrel exit, second environment sensors and electronics detect velocity; if 700 feet per second is exceeded, the fuze rotor is allowed to turn into alignment. At exit from the barrel, the four control fins are deployed by centrifugal force, and they maintain a clockwise spin rate of about 6 revolutions per second

At the preset time, the guidance sequence begins. First, the ± 30-volt section of the battery and electronics is activated; next, the gyro gotcha squib is fired, releasing the gyro; and then the roll-rate sensor and the control gas bottle are activated, unlocking the fins and providing 70 seconds of actuator power. The actuator stops the roll rate and establishes roll control.

One second after roll control is initiated, the gyro spring squib is fired; it mechanically spins the gyro, which is then electrically caged to the body. Two seconds later, the wing squib is fired to unlock the wings, which are extended by a squib-fired piston

Either a ballistic or a glide trajectory, as shown in figure 6, is flown. The glide trajectory permits flyout to extend the range and also to fly under cloud cover with sufficient guidance times to acquire and hit the target. On acquisition of the proper laser code, the gyro is slewed toward the target and fuze arming is completed. Proportional navigation guidance with gravity compensation is employed until impact. The warhead is detonated at impact, and the shaped-charge jet penetrates and destroys the target

Figure 6
Trajectory Modes and Extended Range



Target may be engaged by employing ballistic trajectory or by glide trajectory beneath the clouds

Range may be extended by employing glide mode

Appendix B

Details of Gyro Hardening

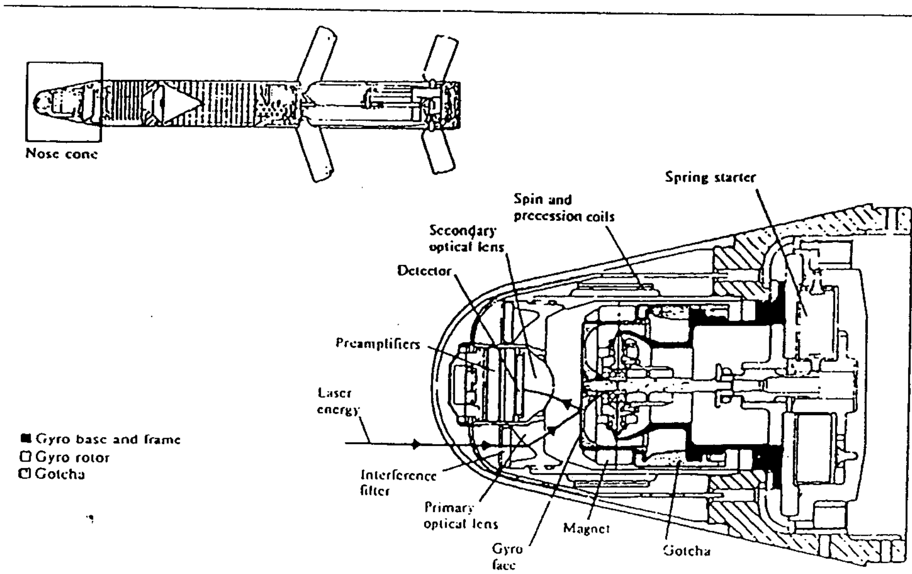
The following description of gyro hardening is extracted from an article "Copperhead—The Evolution of a Revolutionary Weapon," which appeared in *Journal of Defense Research*, vol. 13, no. 2, summer 1981, pages 197 and 198

Implementation of the Copperhead guidance concept was by no means highly complex or more unconventional than that for typical tactical missiles. The challenge was to develop and prove the techniques that are required to make fragile optical, electronic, and gyro components survive an acceleration that is two to three orders of magnitude greater than previous state-of-the-art levels. Fortunately, the Copperhead application was one of an indirect fire weapon system—the projectile does not need to be operative during launch, and mechanical items such as the gyro were not required to function during the launch loads.

The gyro is the most difficult seeker item to harden. The gyro must act as a precision inertial reference source, and it cannot tolerate the large drifts or biases induced by the cannon launch environment. A primary concern was that the extreme launch load would damage the gimbal bearing, causing unacceptable gyro performance. A technique was developed that added a load-carrying flange to a conventional bearing design. At launch, the load transfer bearing deflects under load until the gap between the flanges closes. With the gap closed, the load-carrying area is significantly increased, preventing any further deflection. With the majority of the load carried in the flange area, the bearings are protected, and gyro performance does not change after the cannon launch environmen

The concept of the load transfer bearing is enhanced by the presence of a structural load-carrying sleeve called a "gotcha." The gotcha mechanism (see figure 7) transfers the load created by the gyro rotor to the primary structure and prevents the load from being carried by the gimbals and bearings. The gyro rotor weighs only 0.484 lb, but under a 9,000-g launch its weight is equivalent to 4,356 lb. Thus, the protection afforded by the gotcha to prevent this level from reaching the bearing is crucia

Figure 7
Diagram of Strap-Down Optics Package



Note: Gotcha is engaged, in pre-fire configuration

Appendix C

Homing Artillery Shells

The following description of homing artillery shells is extracted from a translated article by A. Latukhin and K. Morozov, which appeared in *Tekhnika i Vooruzheniya*, November 1975, pages 14 and 15.

Overseas work began in the late 1960s on the development of homing artillery shells for direct and indirect firing. Today extensive efforts are underway to develop 127-, 155-, and 203-mm laser beam homing shells.

For firing such a shell, the artillery subunit spotter, located on the ground or aboard an aircraft (helicopter) within line of sight of the target, illuminates the target with a laser beam. The laser detector, mounted in the shell head, searches for the laser spot on the target. The information received is transmitted to the guidance system, which gives commands to the aerodynamic control surfaces. The shell homes in on the target.

The use of homing shells, experts believe, will make it possible to decrease ammunition expenditure for destroying pinpoint targets to a fraction of that now required. However, the cost of such a shell will more than quadruple, reaching $1,000 for 155-mm shells by some estimates, and up to $2,000 to $5,000 by others.

The main advantage of homing shells over conventional ones is that their hit probability (for one round) will be roughly the same as for a guided missile. It is believed that this will yield considerable savings and simplify the work of supply agencies. The use of these shells will also require a review of artillery and infantry operating tactics. Greater centralization of artillery fire control will be required. Using homing shells will increase the infantry's vulnerability considerably, and massive employment will hardly be possible. Besides, homing shells will permit artillery to fire on tanks and other combat vehicles successfully from indirect fire positions at a considerable distance (10 to 15 km

Foreign specialists feel that such artillery shells will be one of the main and most effective types of weapons of armies of the future.

Prototypes of 155-mm rocket-assisted shells are now being tested. They differ from one another in structural design, configuration of the individual components, and length. The new shell includes a semiactive laser homing head, a control unit, a bursting explosive charge and fuze, a solid propellant motor, and a tail fin that opens in flight. The projectile's control system set includes a laser target designation and illumination station equipped with a telescopic sight and a target tracking device. The station is carried by two men. It is set up at the position on a tripod and serviced by one operator. After the projectile is fired, the target is illuminated by the laser for about 10 second

It has been reported that experimental homing shells hit stationary and moving targets at a distance of 11 km during tests conducted in January 1975. However, foreign experts note that the test models of the controlled projectile have significant shortcomings. The main ones include the need for a laser illumination post that must be within line of sight of the target and the complexity and bulkiness of the command processo

It is felt that the artillery shell flight guidance systems, including deviation sensors, a command device, and control elements should have minimum dimensions, high durability, their own power sources, and low actuator lag (for spin-stabilized shells

It is rather difficult to fulfill all these requirements. It is especially complex to place a large number of various devices in the limited size homing head.

Striving to decrease the size of the shell, designers locate the main portion of the complex equipment, including the computer equipment, on the ground and leave only the sensors and control elements on the projectile. Difficulties with installing guidance system elements in the shell do not make it possible to build a homing artillery shell smaller than 120 mm at the present time