MILE STONES

Soviet SAMs target the West

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Throughout the Cold War era Soviet-built Surface to Air Missiles (SAM) accounted for more losses in Western combat aircraft than any other weapon type used or exported by the Soviets. Russian SAM systems, all evolved from their Soviet era late Cold War forerunners, are now the most capable threat systems in the contemporary globalised weapons markets, capable of defeating all Western systems other than the B-2A and F-22A.

Early Operational Success of the SAM

First generation Soviet SAM development culminated in the S-75/SA-2, which became the most widely deployed and used air defense missile in history. The missile is credited with the demise of the U-2 high altitude reconnaissance aircraft and the development of sophisticated electronic countermeasures by air forces in the West.

The first S-75 batteries were deployed in the Soviet Union in late 1957. The missile's first known kill against a Western aircraft remains disputed. Some sources claim it was a U-2 over China in 1959, some say it was Gary Powers' CIA-operated U-2 lost over Sverdlovsk in May 1960. Many sources also claim a Soviet MiG-19 Farmer was also downed by PVO missileers in the same engagement. An S-75 shot down a US Air Force U-2 flown by Major Rudolf Anderson over Cuba in October 1962. The lethality of the S-75 against the subsonic U-2 rapidly led to the development of the Mach 3 A-11/SR-71 Blackbird.

By 1965 the S-75 was widely deployed in the Soviet sphere of influence, and scored its first kills against combat aircraft. Russian sources claim 4600 launchers were deployed in the Soviet Union alone by 1970.

The S-75 system was deployed to North Vietnam in 1964 to counter US air raids, with US electronic intelligence detecting Fan Song radar emissions in April 1965. The US was ill prepared for the S-75, as only a limited number of aircraft were equipped with radar warning receivers to detect the system, let alone jammers to defeat the Fan Song engagement radar. As the PAVN constructed a series of SAM sites across the north, the Johnson administration refused to authorise attacks on these sites for fear of killing Warsaw Pact or Russian instructors training the PAVN missileers, thus escalating the conflict.

The US Air Force quickly upgraded a number of its subsonic EB-66B and EB-66C Destroyer electronic warfare aircraft and deployed these into the theatre to provide warning to US strike aircraft. The EB-66 deployment was equipped with jammers to defeat Soviet supplied Fire Can radars used by PAVN anti-aircraft artillery batteries. The S-75's V-750 missile could engage targets between 3,000 ft and 50,000 ft, out to 17 nautical miles range, its limited G capability made it relatively easy for supersonic fighters to evade it by high G turns, providing they knew the missile was inbound.

S-75 Dvina / SA-2 Guideline on SM-90 launcher.

The PAVN's S-75 batteries drew first blood in July 1965 when a flight of four F-4Cs was engaged, with one Phantom killed and three damaged. Not equipped with warning receivers, they were blind to attack, and likely did not hear warning calls produced by an EB-66 orbiting nearby. Three days later the US Air Force responded by attacking two S-75 sites with F-105s, supported by EB-66 jammers. The SAM batteries had since been redeployed and six F-105s were lost in a flak trap set up for them. In August 1965, the US Navy fell into the same trap after an A-4 was killed by an S-75, a subsequent Alpha strike saw six aircraft lost to a well laid flak trap while attempting to attack the SAM site.

The PAVN and their Warsaw Pact advisers played this shell game over and over again, constructing dozens of revetted SAM sites and repeatedly redeploying the missile batteries, doing so frequently enough to stay ahead of the US targeting cycle. In technical terms, the PAVN was operating inside the US OODA (Observation Orientation Decision Action) loop.

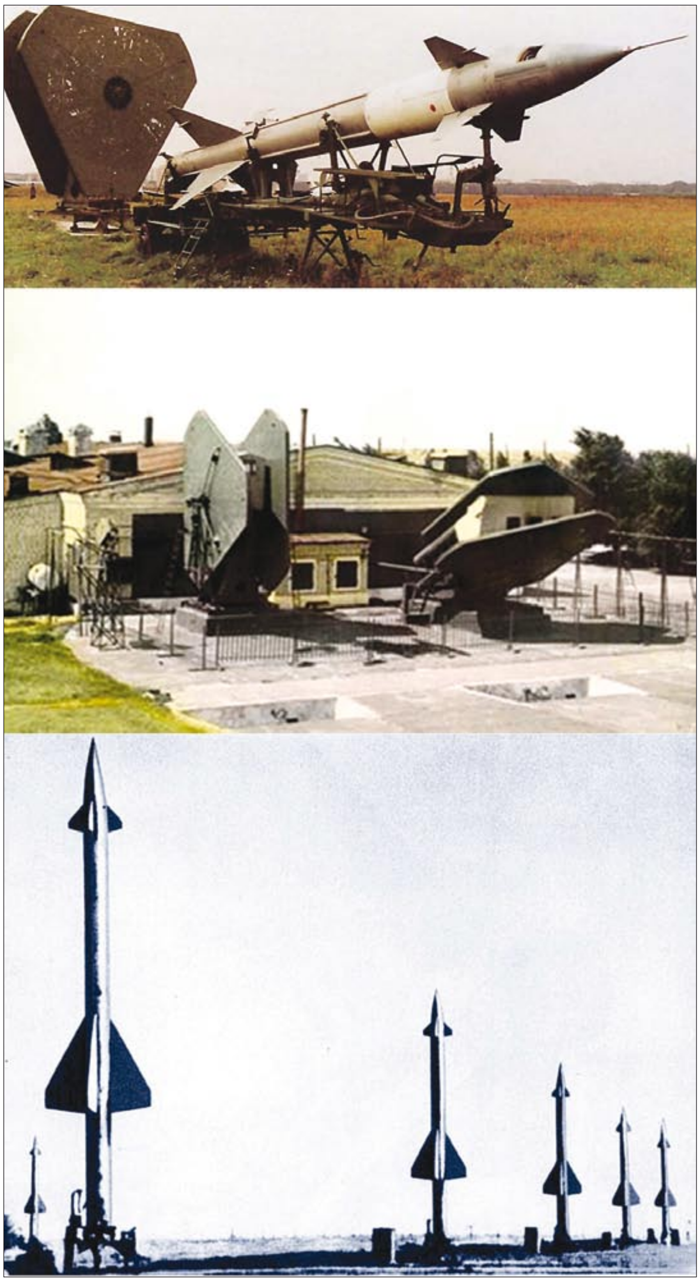
What followed was an intensive effort by both sides to adapt tactics and deploy electronic countermeasures, and counter-countermeasures. The evolution of the anti-radiation missile, and specialized Navy Iron Hand and Air Force Wild Weasel aircraft was a direct response to the success of the S-75. Many tactical measures used to evade the S-75 proved counterproductive, for instance flying F-105 Thunderchiefs in at very low altitudes simply drove up losses to anti-aircraft artillery fire.

The S-75 Dvina SAM system changed the face of aerial combat forever, during the 1965 Rolling Thunder campaign, and set the pattern for the remaining decades of the Cold War.

SNR-75 Fan Song engagement radar, U-2 reconnaissance aircraft, PR-11 transloader and SM-90 launcher.

Early Development

The SAM's origins lie in the post World War II Soviet effort to strip occupied Germany and Eastern Europe of as much German technology, design documentation and design personnel as feasible. This was the Soviet mirror activity to the Allied Paperclip effort.
Amongst the technology so acquired was the German EMW Wasserfall W1, W-5 and W-10 FLA Rakete, which almost achieved operational status, with some German sources claiming that some early trial rounds were successfully launched at allied bombers. The Soviets also acquired samples of the less capable Henschel Hs-117 Schmetterling FLA Rakete design.
The Wasserfall was an offshoot of Werner Von Braun's A-4/V-2 ballistic missile, fitted with additional cruciform wings and used a different propellant system, as the missiles could sit on a launch pad for days awaiting a target. The Wasserfall's engine, which later had a profound influence on Russian SAM and ballistic missile propellant design, used a 250 atmosphere nitrogen pressurized self-igniting or hypergolic propellant mix, with a Tonka or Vinyl Isobutyl Ether fuel and SV-Stoff (Salbei) oxidizer. The oxidiser comprised 90 per cent nitric acid and 10 per cent sulphuric acid. The missile employed manual radio command uplink guidance using a radar beacon on the aft of the missile. This design feature became prominent in Soviet SAMs (refer Milestones Sept/Oct 2006 for detailed analysis).
In May 1946 a classified Soviet report labeled 1017-419 'Questions on Rocket/Jet Weapons' proposed the further development of acquired German ballistic missile and SAM technology. As a result, the NII-88 design and development bureau resurrected the Wasserfall as the R-101 and the Schmetterling as the R-103. Russian sources agree that this effort was not successful, with frequent launch failures during trials. The Russians learned that proper guidance systems were required for such weapons and that multi-disciplinary design teams were required, mirroring earlier Soviet difficulties with nuclear weapons development.
The Soviets recognized the potential of the SAM as an air defence weapon, as their fighter aircraft were challenged in performance when trying to intercept the fast and high flying US B-29, B-50 and B-36 bombers. With the B-47 and B-52 in development, the Soviets needed a technological strategy for dealing with these threats. The result was the launch in 1950 of a new program, the 'System 25' or P-25 Berkut (Golden Eagle), later designated by the NATO codename of SA-1 Guild. Provision of a layered SAM belt around Moscow was a top priority, to defend the centre of Soviet government apparatus and nucleus of its military industrial complex from nuclear attack by US and British strategic bombers.
Moscow was to be ringed with two concentric overlapping belts of acquisition and search radars, the inner at a 25-30 km radius, the outer at a 250 km radius. These systems were tied together via air defence headquarters and used the decimeter band VNIIRT Kama radar. The Kama radars were to be used to cue the Article B-200 engagement radars for the V-300 SAM round, to be designed by the Lavochkin bureau.
A curious part of an early Soviet plan was a scheme to modify Tu-4 Bull (reversed engineered Boeing B-29 Superfortress) aircraft as interceptors, to be armed with the large G-400 air to air missile, to be based on technology developed for the V-300. A further component of this system was to be the D-500, a modified Tu-4 Airborne Early Warning and Control system, intended to support the ground based radar network. The airborne component of the air defence system was soon abandoned as too ambitious.
The first prototype trials were performed on test ranges in 1952, with 81 test launches conducted by 1953, using the Tu-4 as the drone target. The first operational S-25 systems were deployed in 1954, with IOC claimed in the 1955-56 timeframe. Russian sources claim that a key design objective for the system was to be able to track and engage twenty aircraft concurrently.
All SAM battery components were sited in fixed hardened concrete installations intended to survive hits from US standard 2,000 lb high explosive bombs, with extensive earthworks and camouflage applied.
The B-200 Yo-Yo engagement radar with its characteristic (and unusual) triangular antenna system transmitted two narrow beams, one to track the target and one the command link guided missile round. One antenna was used for azimuthal tracking, another for elevation tracking.



S-25 Berkut / SA-1 Guild battery components, top to bottom: V-300 missile round and Yo-Yo antenna, Yo-Yo radar antennas, deployed missile battery on fixed launch pads. The SA-1 was a static system, which shared many design features with the German Wasserfall from which it evolved.

S-75 Dvina / SA-2 Guideline battery components top to bottom: V-750 missile round on SM-90 launcher, PR-11A transloader and SM-90, SNR-75 Fan Song radar, P-12 Spoon rest radar.

The S-25 missile design showed its Wasserfall heritage. The single stage liquid propellant rocket was deployed by a semi-trailer transloader, which doubled up as an elevating gantry to position the missile round on a fixed launch pad, in the manner of the A-4/V-2 and Wasserfall. The missile employed a unique control arrangement, with nose-mounted canards for pitch/yaw control, ailerons for roll control, and tailfins for post launch alignment of the missile trajectory as it accelerated to speed.

The 9 tonne thrust class powerplant was a direct derivative of the R-101 'Wasserfall-ski' engine, using an improved propellant mix.

S-25 Berkut systems and associated Yo-Yo radars were deployed primarily to defend Moscow and Leningrad in concentric fixed SAM belts as initially planned. Soviet plans for the S-25 included a mobile launcher scheme on railroad cars, and a tracked mobile system, both of which were cancelled in favour of a new SAM system design.

The success of the cumbersome SA-1 Guild led to the S-75 or SA-2 Guideline system, which became the most widely exported SAM system produced by the Soviets. The SA-2 played a key role in the Vietnam conflict but also formed the backbone of the first generation Soviet supplied SAM belts deployed by Egypt and Syria. The SA-2 was also prominent in the Warsaw Pact SAM belts in Germany, Czechoslovakia, Poland and Hungary, as well as being exported to almost every Soviet client during the Cold War. China reverse engineered the SA-2 during the 1960s, as the HQ-1, and later developed an indigenous derivative, the HQ-2, also widely exported. Much of Iran's post Shah SAM system comprises Chinese supplied HQ-2s, replacing the US supplied Hawk SAM systems.

The S-75/SA-2 was a new design but also showed its heritage. Two key design requirements for the S-75 were better range performance compared to the S-25 and much better deployability, as concreted pads were time consuming and expensive to construct.

The S-75 missile round retained the cruciform wing and nose canard design of the S-25 round, as well as the command link guidance scheme. While the cruise engine employed a similar hypergolic propellant mix to the S-25, it used a mono-propellant driven turbopump to feed the new Isayev S2.711 engine. The S-75 missile used a new Kartukov designed solid propellant first stage to accelerate the missile off its launcher.

The new S-75 was designed for much higher mobility, using a towed SM-90 trainable single rail launcher for the missile, which was carried in the field by a semi-trailer PR-11 transloader, towed by a Zil 6 x 6 tractor. Once the SM-90 launcher was in position, and leveled, the missile round was transferred to its launch rail and locked into position. The SM-90 would then be elevated and steered to point the missile in the direction of the target.

A S-75 battery comprised six SM-90 launchers clustered around a single SNR-75 Fan Song engagement radar. The Fan Song could control up to two missile rounds concurrently against a single target.

The Fan Song's basic arrangement was similar to the earlier Yo-Yo. But with two massive and separate antennas for elevation and azimuth tracking, the Fan Song used a pair of fixed trough antennas mounted on a single towed trailer, with a third dish antenna for the missile command uplink. It could produce two fan shaped 'flapping' beams, one for azimuth tracking, the other for elevation tracking, both of the target and a beacon in the tail of the missile.

Targets were typically acquired by the VHF band P-12 Spoon Rest acquisition radar, which used a characteristic horizontal boom mounting two stack arrays of Yagi antennas, better known for their use as rooftop TV aerials. Once acquired by the Spoon Rest, the target position was relayed to the Fan Song, which would slew the whole antenna package in the direction of the target and initiate angle and range tracking for a missile shot. A pair of missiles would be fired and an analogue computer used to generate steering commands to fly the missile to a collision with its target, using a radio uplink. A radio proximity fuse was used for the high explosive warhead.

References:

Marshall L. Michel, III, Clashes: Air Combat Over North Vietnam, 1965-1972, Naval Institute Press, 2007.

Said Aminov, S-25 Berkut, Vestnik PVO, URL: http://pvo.guns.ru (Russian language).

Kopp C., Milestones: Genesis of the Surface to Air Missile, Defence Today - September/October 2006, URL: http://www.ausairpower.net/DT-MS-1006.pdf